SCIENCE-IX

MODULE - 6

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MOTION

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MOTION

INTRODUCTION

Motion is a very preliminary state of action associated with living and non-living beings. The study of the displacement, velocity and acceleration associated with moving bodies can make us understand the motion of bodies. To have an in-depth study of motion, equational representation and graphical analysis of various related quantities in motion with time is also done.

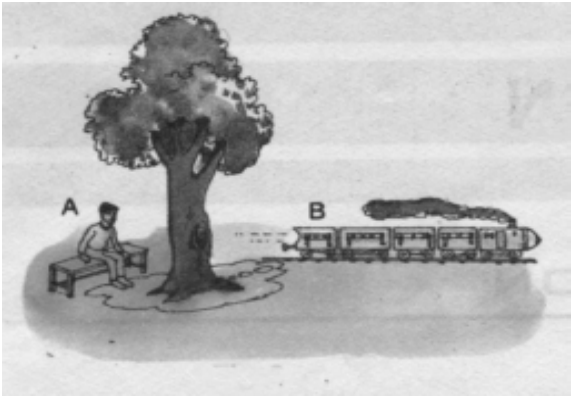
When a body does not change its position with time, we can say that the body is at **rest**. While if a body changes its position with time, it is said to be in **motion**.

(i) An object is said to be a **point object** if it changes its position by distances which are much greater than its size.

(ii) A point or some stationary object with respect to which a body continuously changes its position in the state of motion is known as **origin** or **reference point**.

Describing Motion :

When a tree, is observed by an observer A sitting on a bench, the tree is at rest. This is because position of the tree is not changing with respect to the observer A.



Now, When the same tree T is observed by an observer sitting in a superfast train moving with a velocity v, then the tree is moving with respect to the observer because the position of tree is changing with respect to the observer B.

Vectors : Physical quantities defined with both magnitude and direction are called vector quantities. They should also satisfy the law of vector addition.

Examples: Velocity, acceleration, force, displacement, momentum, weight, torque, electric field, magnetic filed, etc.

Scalars : Physical quantities having only magnitude are called scalar quantities.

Examples: Mass, time, distance, speed, work, power, energy, electric charge, area, volume, density, pressure, electric potential, temperature, etc.

DIFFERENCE BETWEEN SCALAR & VECTOR QUANTITIES :

	Scalar Quantities	Vector quantities
1	These are completely specified by their magnitude only.	These are completely specified by their magnitude as well as direction.
2	These change by change of their magnitude only	These change by change of either their magnitude or direction or both
3	These are added or subtracted by laws of ordinary algebra like 4m+5m=9m.	These are added or subtracted by laws of vector addition.

Newton's Thought
Discuss whether the walls of your classroom are at rest or in motion. **Explanation** The walls of our classroom are at rest with respect to the ground or earth. But, they are in motion with respect to an object or an observer outside the earth. This is because the earth is moving about its own axis as well as it is revolving around the sun. Thus, the state of rest and motion are not absolute, they are relative terms.

TYPES OF MOTION

(A) According to Directions

(i) One dimensional motion is the motion of a particle moving along a straight line.

(ii) Two dimensional motion A particle moving along a curved path in a plane has 2-dimensional motion.

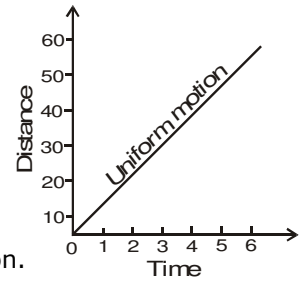
(iii) Three dimensional motion Particle moving in space has 3-dimensional motion.

(B) According to state of motion

A moving body may cover equal distances in equal intervals of time or different distances in equal intervals of time. On the basis of above assumption, the motion of a body can be classified as uniform motion and non-uniform motion.

(i) Uniform motion:

Time (in second)	0	1	2	3	4	5	6
Distance covered (in metre)	0	10	20	30	40	50	60



When a body covers equal distances in equal intervals of time however small may be time intervals, the body is said to describe a uniform motion.

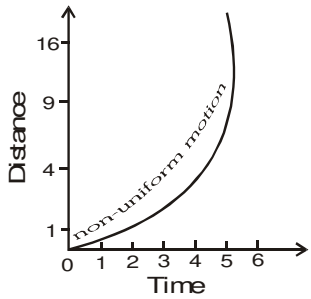
Example of uniform motion –

(a) An aeroplane flying at a speed of 600 km/h

(b) A train running at a speed of 120 km/h

(c) Light energy travelling at a speed of 3×10^8 m/s

(d) A spaceship moving at a speed of 100 km/s



(ii) Non-uniform motion:

Time (in second)	0	1	2	3	4
Distance (in metre)	0	1	4	9	16

When a body covers unequal distances in equal intervals of time, the body is said to be moving with a non-uniform motion.

Example of non-uniform motion –

(i) An aeroplane running on a runway before taking off.

(ii) A freely falling stone under the action of gravity.

(iii) An object thrown vertically upward.

(iv) When the brakes are applied to a moving car.

(C) According to path

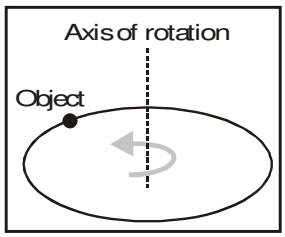
(i) Linear motion : A body has linear motion if it moves in a straight line or path.

Ex. (a) Motion of a moving car on a straight road.

(b) Motion of a ball dropped from the roof of a building.

(ii) Circular (or rotational) Motion : A body has circular motion if it moves around a fixed point.

A vertical passing through the fixed point around which the body moves is known as axis of rotation.



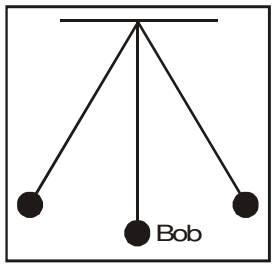
Ex. (a) Motion of an electric fan.

(b) Motion of merry-go-round

(c) Motion of a spinning top.

(iii) Vibratory motion :

A body has vibratory motion if it moves to and fro about a fixed point.



Ex. (a) Motion of a pendulum of a wall clock.

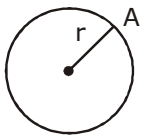
(b) Motion of a simple pendulum.

DISTANCE & DISPLACEMENT

(i) The actual path length between the initial and final positions of the particle gives the **distance** covered by the particle.

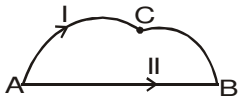
(ii) The minimum distance between the initial and final positions of a body during that time interval is called **displacement**.

Analysis



(i) Distance travelled is a scalar quantity while displacement is a vector quantity. Eg. if a body moves along the circumference of a circle of radius r, then the distance travelled is given by $2\pi r$, while the displacement is given by zero.

(ii) When a body continuously moves in the same straight line and in the same direction then displacement will be equal to the distance travelled. But if the body changes its direction while moving, then the displacement is smaller than the distance travelled.

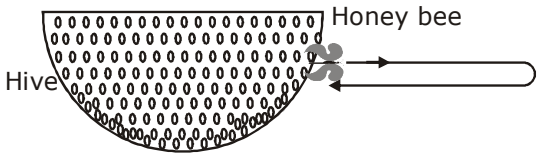


Displacement $\leq$ Distance

DIFFERENCES BETWEEN DISTANCE AND DISPLACEMENT		
	Distance	**Displacement**
1	It is defined as the actual path traversed by a body.	It is the shortest distance between two points which the body moves.
2	It is a scalar quantity	It is a vector quantity
3	It can never be negative or zero	It can be negative, zero or positive.
4	Distance can be equal to or greater than displacement	Displacement can be equal to or less than distance.
5	Distance travelled is not a unique path between two points.	Displacement is a unique path between two points.
6	The distance between two points gives full information of the type of path followed by the body.	Displacement between two points does not give full information of the type of path followed by the body.
7	Distance never decreases with time. for a moving body it is never zero.	Displacement can decrease with time for a moving body it canbe zero.
8	Distance in SI is measured in metre	Displacement in SI is measured in metre.

Newton's Thought

A honeybee leaves the hive and travels 2m before returning. Is the displacement for the trip the same as the distance travelled? If not, why not.



Explanation

No, the displacement and the distance are not same. This is because the displacement is the change of position of object in motion while distance is length of path travelled by it.

Here, the distance travelled = 2m

While, the displacement = 0, because the position of honey bee is not changed.

SPEED AND VELOCITY

Speed : The distance travelled in one second is called speed It is a scalar quantity. Its SI unit is m/s. Speed always remains positive.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} (\text{m/s})$$

$$\text{Speed} = \frac{s_2 - s_1}{t_2 - t_2} = \frac{\Delta s}{\Delta t}$$

Where Δs = distance in time interval Δt.

Velocity : The displacement in one second is called velocity. It is a vector quantity expressed in m/s. Velocity can be positive, negative or zero.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}} (ms^{-1})$$

$$\text{Velocity} = \frac{\Delta s}{\Delta t}$$

Where Δs = displacement travelled in time interval Δt.

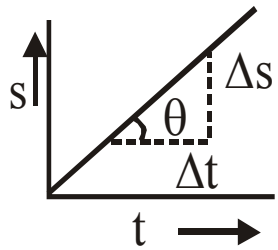
Speed	Velocity
1. Scalar quantity	1. Vector quantity.
2. Rate of distance covered.	2. Rate of displacement.
3. Cannot be zero for a moving body.	3. Can be zero, +ve or –ve.
4. Speed is velocity without direction.	4. Velocity is directed speed.
5. Speed in SI unit is measured in ms^{-1}.	5. Velocity in SI unit is measured in ms^{-1}.

(i) Unit : In M.K.S. system = ms^{-1}

In C.G.S. system = Cms^{-1}

(ii) If distance time graph is a straight line, then speed can be given by the slope of the line,

i.e. $v = \frac{\Delta s}{\Delta t}$



$$\text{slope} = \frac{s_2 - s_1}{t_2 - t_1}$$

(iii) The area of velocity time graph gives distance travelled.

(iv) Conversion from km/hr to m/sec.

$$\frac{1\text{km}}{\text{hr}} = \frac{1000}{60 \times 60} \text{m/s} = \frac{5}{18} \text{m/s}.$$

TYPES OF SPEED

(a) Average and Instantaneous speed

◈ **Average speed :** The ratio of distance travelled by a body to the total time taken, when the motion can be with varying speeds for various intervals of time.

$$\text{Average Speed} = \frac{\text{Total Distance}}{\text{Total Time taken}}$$

OR

It is obtained by dividing the total distance travelled by the total time interval. i.e.

$$\text{Average speed} = \frac{s_2 - s_1}{t_2 - t_1} = \frac{\Delta s}{\Delta t}$$

(i) Average speed is a scalar, while average velocity is a vector.

(ii) For a given time interval average velocity is single valued, while average speed can have many values depending on path following.

(iii) If after motion body comes back to its initial position $\vec{v}_{av} = 0$ [as $\Delta\vec{r} = 0$], but $v_{av} > 0$ and finite (as $\Delta s > 0$)

(iv) For a moving body average speed can never be –ve or zero (unless t = 0), while average velocity can be i.e. $v_{av} > 0$ while $\vec{v}_{av} > = \text{or} < 0$

(v) In general average speed is not equal to magnitude of average velocity (as $\Delta s \neq |\Delta\vec{r}|$). However it can be so if the motion is along a straight line without change in direction (as $\Delta s = |\Delta\vec{r}|$)

(vi) If a particle travels distances L_1, L_2 L_3 at speeds v_1, v_2, v_3 etc respectively, then

$$v_{av} = \frac{\Delta s}{\Delta t} = \frac{L_1 + L_2 + \ldots + L_n}{\frac{L_1}{v_1} + \frac{L_2}{v_2} + \ldots + \frac{L_n}{v_n}} = \frac{\sum L_i}{\sum \frac{L_i}{v_i}}$$

(vii) If a particle travels at speeds v_1, v_2 etc for intervals t_1, t_2 etc respectively, then

$$v_{av} = \frac{v_1 t_1 + v_2 t_2 + \ldots}{t_1 + t_2 + \ldots} = \frac{\sum v_i t_i}{\sum t_i}$$

(viii) If a particle moves a distance at speed v_1 and comes back with speed v_2, then

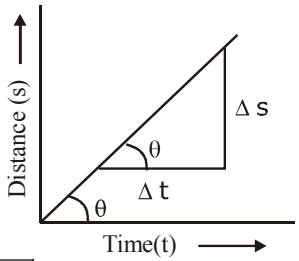
average speed $v_{av} = \frac{2v_1 v_2}{v_1 + v_2}$ $\quad (\vec{v}_{av} = 0)$

(ix) If a particle moves for two equal time intervals

$$v_{av} = \frac{v_1 + v_2}{2}$$

◈ **Instantaneous speed** :

The speed of a body at a particular instant of time is called its instantaneous speed.



$$\text{Instantaneous speed} = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

(b) Uniform and Non uniform speed

◈ **Uniform speed** :

If the time speed graph of an object is a straight line parallel to time axis then the body is moving with a uniform speed.

◈ **Non-uniform speed** :

If the speed of a body is changing with respect to time it is moving with a non-uniform speed. Its graph is not a straight line.

TYPES OF VELOCITY

(a) Average Velocity:

Total displacement divided by total time is called an average velocity.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

$$V_{av} = \frac{x_2 - x_1}{t_2 - t_1}$$

OR

The arithmetic mean of initial velocity and final velocity for a given time period, is called average velocity.

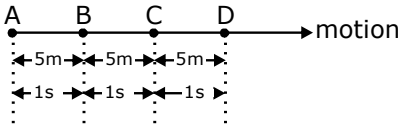
$$\text{Average velocity} = \frac{\text{Initial velocity + Final velocity}}{2}$$

$$V_{av} = \frac{u + v}{2}$$

where u = initial velocity, v = final velocity

(b) Uniform & Non uniform Velocity

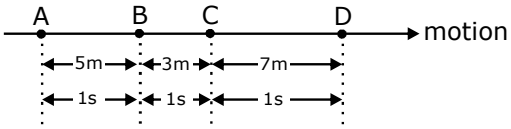
◈ **Uniform velocity**



Body moving with uniform velocity

When a body covers equal displacement in equal interval of time, the body is said to be moving with a uniform velocity.

◈ **Non-uniform velocity/variable velocity :**

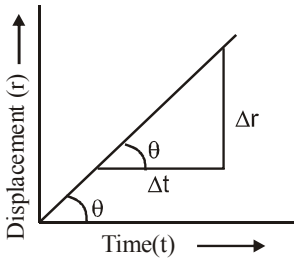


Body moving with non-uniform velocity

When a body covers unequal displacement in equal intervals of time, the body is said to be moving with variable velocity.

Instantaneous velocity :

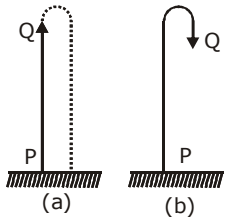
The velocity of a body at a particular instant of time is called its instantaneous velocity.



$$\text{Instantaneous velocity} = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$$

Newton's Thought

A particle is thrown vertically upwards under gravity. What are the signs of displacement and velocity in the given situations (a) & (b) (P to Q):



Explanation

(a) Here, displacement and velocity (average & instantaneous) both are positive.

(b)Here, displacement is positive. Instantaneous velocity is negative & average velocity is positive.

ACCELERATION

The rate at which the velocity changes is called acceleration. It is a vector quantity. Its SI unit is m/s^2 or ms^{-2}.

(i) Rate of change of velocity is called acceleration

(ii) The change in velocity may be in magnitude or in direction or both.

i.e. $\boxed{a = \frac{v-u}{t}}$

(iii) Unit of acceleration = m/s^2 or ms^{-2}

◈ **Deceleration or Retardation :** If the change in velocity is –ve ie. if velocity of a body decreases, the acceleration is called deceleration or retardation.

◈ **Uniformly accelerated motion :** When the change in velocity is same in equal time intervals, the motion called uniformly accelerated motion, otherwise, it is non-uniformly accelerated motion.

TYPES OF ACCELERATION

(i) Uniform & Non uniform acceleration

◈ **Uniform acceleration**

If a body travels in a straight line and its velocity increases by equal amounts in equal intervals of time then it is said to be in state of uniform acceleration e.g. motion of a freely falling body.

◈ **Non uniform acceleration**

A body has a non-uniform acceleration if its velocity increases by unequal amounts in equal intervals of time.

(ii) Average & Instantaneous acceleration

◈ **Average acceleration** :

$$\boxed{a_{av} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t}}$$

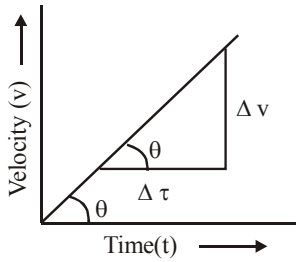
[here it is assumed that acceleration remains the same during the time interval Dt.]

If a body travels with a uniform acceleration a_1 for a time interval t_1 and with uniform acceleration a_2 for a time interval t_2 then

$$\boxed{a_{av} = \frac{(a_1 t_1 + a_2 t_2)}{(t_1 + t_2)}}$$

◈ **Instantaneous acceleration** :

The acceleration of a body at any instant is called its instantaneous acceleration.



e.g. $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$

(iii) If the velocity of a body decreases, then it will experience a negative acceleration which is called deceleration or retardation.

Acceleration is determined by the slope of time-velocity graph.

$$\boxed{\tan\theta = \frac{dv}{dt}}$$

(i) If the time velocity graph is a straight line, acceleration remains constants.

(ii) If the slope of the straight line is positive, positive acceleration occurs.

(iii) If the slope of the straight line is negative, negative acceleration or retardation occurs.

(iv) Larger the slope (tan θ) longer will be the straight line.

(v) If the time velocity graph is a curve, then the acceleration changes continuously.

EQUATIONS OF MOTION

A. Uniform Motion : If x_i and x_f are the initial and final positions respectively of a-moving particle, the motion is defined by, velocity $v = \frac{x_f - x_i}{t}$ and v will be constant.

B. Non-uniform Motion : $(x_f - x_i)$ varies in equal time intervals. So velocity varies.

C. Average velocity = $\frac{\text{Total displacement}}{\text{Total time taken}}$

D. Average speed = $\frac{\text{Total distance travelled}}{\text{Total time taken}}$

E. Uniform acceleration : If u and v are the initial and final velocities in time 't', then acceleration $a = \frac{v-u}{t}$. It is a constant.

F. In uniform acceleration (only), the average velocity is given by, $v_{av} = \frac{v+u}{2}$.

G. For uniformly accelerated motion,

(i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ and (iii) $v^2 = u^2 + 2as$

◈ **Motion under uniform acceleration**

Suppose a body starts with initial velocity u, moving with an acceleration attains a velocity v after time t travels a distance s, then motion can be described by following equations.

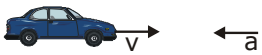
(a) $v = u + at$ **(b)** $s = ut + \frac{1}{2}at^2$ **(c)** $v^2 = u^2 + 2as$

Newton's Thought

A car is travelling along a straight road and is decelerating. Does the car's acceleration necessarily have a negative value?

Explanation

We begin with the meaning of the term "decelerating," which has nothing to do with whether the acceleration 'a' is positive or negative. The term means only that the acceleration is opposite to the velocity and indicates that the moving object is slowing down.



v = +ve; a = –ve

v = –ve; a = +ve

(i) One possibility is that the velocity of the car points to the right (the positive direction) and acceleration points opposite i.e. to the left (the negative direction).

(ii) Another possibility is that the velocity of the car points to the left (the negative direction) and acceleration points opposite i.e. to the right (the positive direction).

DERIVATION OF EQUATIONS OF MOTION

(i) v = u + at

Let a body have an initial velocity 'u' and an uniform acceleration 'a'. At any time 't', if 'v' is the velocity,

Acceleration = $\frac{\text{Change in velocity}}{\text{Time taken}} = \frac{v-u}{t}$

$\therefore \quad v = u + at$

(ii) $s = ut + \frac{1}{2}at^2$

Let the displacement in time 't' be 's' with uniform acceleration 'a'. The average velocity is given by

$$v_{av} = \frac{\text{initial velocity} + \text{final velocity}}{2}$$

$$\therefore \quad v_{av} = \frac{u+v}{2}$$

Displacement $s = \left(\frac{u+v}{2}\right)t$

Applying first eq. $s = \left(\frac{u+u+at}{2}\right)t;$

$$s = \frac{(2u+at)}{2} \times t$$

$$s = ut + \frac{1}{2}at^2.$$

(iii) $v^2 = u^2 + 2as$

Velocity at any time, v = u + at

$s = \left(\frac{u+v}{2}\right)t \qquad \because \frac{v-u}{t} = a \quad \therefore \frac{v-u}{a} = t$

$$s = \left(\frac{v+u}{2}\right)\left(\frac{v-u}{a}\right)$$

$v^2 = u^2 + 2as$

(A) It may be remembered always that these equations are applicable only for **constant acceleration** or **Uniform Acceleration**.

(B) The equations of motion under gravity can be obtained by replacing acceleration by acceleration due to gravity (g) and can be written as follows :

(C) When the body is coming towards the centre of earth

(a) $v = u + gt$; **(b)** $h = ut + \frac{1}{2}gt^2$; **(c)** $v^2 = u^2 + 2gh$

(D) When a body is thrown upwards with some initial velocity, then a retardation produced due to attraction of the earth. In equations of motion, a is replaced by (–g) and thus equations become.

(a) $v = u - gt$; **(b)** $h = ut - \frac{1}{2}gt^2$; **(c)** $v^2 = u^2 - 2gh$

(E) Distance covered by a body in n^{th} sec. i.e.

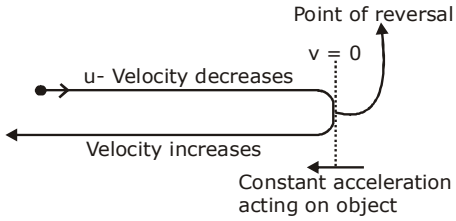
$$s_n = u + \frac{1}{2}a(2n - 1)$$

Newton's Thought

An object moving with a constant acceleration can certainly slow down. But can an object ever come to a permanent halt (stop) if its acceleration truly remains constant? Explain.

Explanation

An object moving with a constant acceleration will slow down if the acceleration is opposite to the velocity. However, if the acceleration remains constant the object will never come to a permanent halt. As time increase, the magnitude of the velocity will get smaller and smaller. At some time, the velocity will be instantaneously zero. An instant after the velocity is zero, the magnitude of the velocity will begin increasing in the same direction as the acceleration. As time increases, the velocity of the object will then increase in the same direction as the acceleration. In other words, if the acceleration truly remains constant, the object will slow down, stop for an instant, reverse direction and then speed up.



BODY FALLING FREELY UNDER GRAVITY

A body released near the surface of the earth is accelerated downward under the influence of force of gravity.

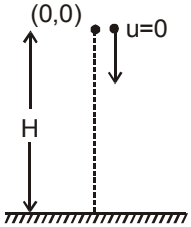
(a) Time of Flight :

from equation $S = ut + \frac{1}{2}at^2$

$S = -H$, $u = 0$, $a = -g$

$t = T$ (Let assume)

$\Rightarrow \quad -H = (0)T - \frac{1}{2}gt^2 \Rightarrow T = \sqrt{\frac{2H}{g}}$



(b) Final Velocity when body reaches the ground

from $v^2 - u^2 = 2as$

$s = -H \qquad v = v_f \quad u = 0 \quad a = -g$

$\Rightarrow \qquad v_f^2 - 0 = 2(-g)(-H) \Rightarrow v_f = \sqrt{2gH}$

Assuming u = 0 for a freely falling body :

(i) As $h = \left(\frac{1}{2}\right)gt^2$ i.e. $h \propto t^2$

Distance fallen in time t, 2t, 3t etc will be in the ratio of $1^2 : 2^2 : 3^2$ ..... i.e. square of integers.

(ii) The distance fallen in n^{th} sec $= \frac{1}{2}g(2n-1)$

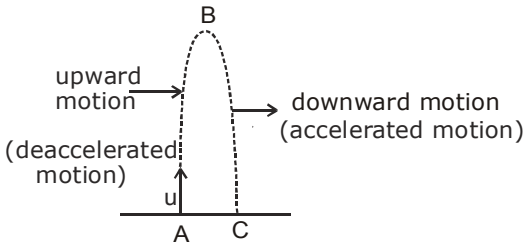
so distance fallen in I^{st}, 2^{nd}, 3^{rd} sec will be in the ratio 1 : 3 : 5 i.e. odd integers only.

BODY IS PROJECTED VERTICALLY UP

It includes two types of motion

(i) Decelerated motion from A to B because the direction of velocity and acceleration is opposite. So speed decreases

(ii) Accelerated motion from B to C because the direction of velocity and acceleration is same (downward). So speed increases



(a) Time of flight :

It is the time taken by the particle to reach the ground. If the particle is thrown vertically upward with initial velocity u then

$u_i = u$

$a = -g$ (take downward direction negative)

from equation

$S = ut + \frac{1}{2}at^2 \Rightarrow S_{net} = 0$ (when particle again reaches the ground)

$t = T$ (time of flight)

$0 = uT - \frac{1}{2}gT^2 \Rightarrow T = \frac{2u}{g}$

(b) Maximum Height :

from $v^2 = u^2 + 2as$

at maximum height $v = 0$, $s = H_{max}$

$\Rightarrow 0 = u^2 - 2gH_{max} \Rightarrow \qquad H_{max} = \frac{u^2}{2g}$

(c) Final velocity

from $v = u + at$

$v = v_f \quad a = -g \qquad t = T = \frac{2u}{g} \Rightarrow v_f = u - g\left(\frac{2u}{g}\right)$

$v_f = -u$

i.e. the body reaches the ground with the same speed with which it was thrown vertically upwards as it thrown vertically upward.

Taking initial position as origin and direction of motion (i.e. vertically up) as positive.

(a) At the highest point $v = 0$ (b) $a = -g$

◈ It is clear that in case of motion under gravity

(a) Time taken to go up is equal to the time taken to fall down through the same distance.

(b) The speed with which a body is projected up is equal to the speed with which it comes back to the point of projection.

(c) The body returns to the starting point with the same speed with which it was thrown.

DISPLACEMENT- TIME GRAPH

⇒ The slope of displacement time (x – t) graph gives the velocity of motion. One can find the velocity of motion, finding the slope of x - t graph. To find the slope,

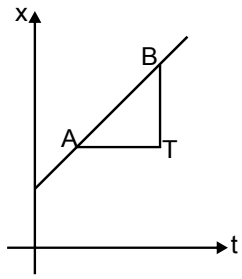
(i) Select any two points on the graph A and B.

(ii) Draw a right triangle below the graph (ABT)

(iii) Find the length of BT and AT from the axis

(iv) Take the ratio of BT to AT

The ratio has the units of velocity.



$$\text{Slope} = \frac{BT}{AT} = \frac{\text{Displacement}}{\text{Time taken}} = \text{Velocity}$$

⇒ If x-t graph is a straight line, then there may be

(i) State of rest – parallel to time axis

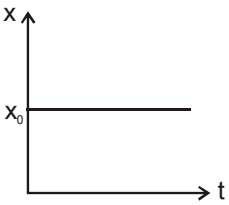
(ii) uniform motion – inclined to time axis.

The slope of the straight line is a measure of velocity of motion.

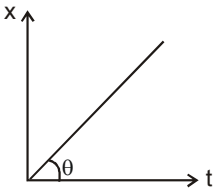
⇒ If the x – t graph is not a straight line, the motion will be a non-uniform motion – accelerated motion.

For example, a body dropped from a height undergoes free fall satisfying the relation $y = \frac{1}{2}gt^2$.

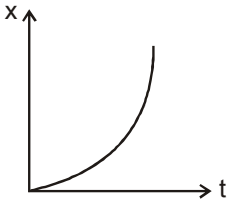
Displacement- time graph (examples)

(1) 

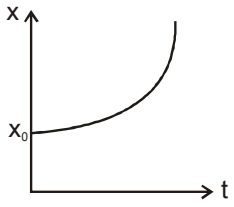
Body is at rest at x_0.

(2) 

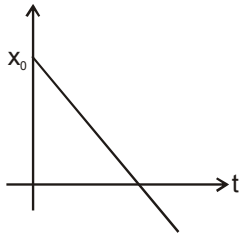
Body starts from origin and is moving with speed tan θ away from origin.

(3) 

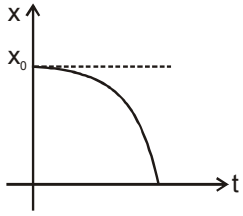
Body starts from rest from origin and moves away from origin with increasing speed velocity and positive acceleration.

(4) 

Body starts from rest from $x = x_0$ and moves away from origin with increasing velocity or +ve acceleration.

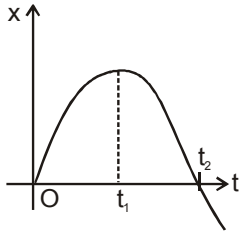
(5) 

Body starts from $x = x_0$ and is moving toward the origin with constant velocity passes throw origin after same time and continues to move away from origin.

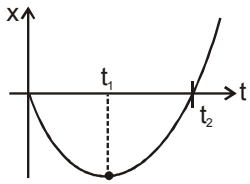
(6) 

Body starts from rest at $x = x_0$ and then moves with increasing speed towards origin

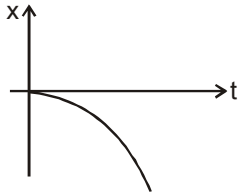
$\therefore$ acceleration is –ve

(7) 

Body starts moving away from origin with some initial speed. Speed of body is decreasing till t_1 and it becomes 0 momentarily of $t = t_1$ and At this instant. Its reverses its direction and move towards the origin with increasing speed.

(8) 

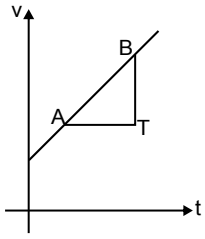
Body starts from origin moves away from origin in the –ve x-axis at $t = t_1$ with decreasing speed and at $t = t_1$ it comes at rest momentarily, Reverses its direction moves towards the origin the increasing speed. Crosses the origin at $t = t_2$.

(9) 

Body starts from origin from rest and moves away from origin with increasing speed.

VELOCITY -TIME GRAPH

⇒ The slope of velocity-time (v – t) graph gives the acceleration of motion.



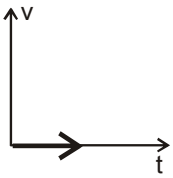
Slope of v – t graph is, $\frac{BT}{AT} = \frac{\text{Change in velocity}}{\text{Time taken}}$

⇒ If v – t graph is a straight line, then there may be

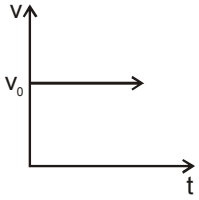
(i) uniform motion –parallel to time axis

(ii) non-uniform motion – inclined to time axis.

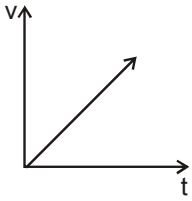
Velocity -time graph (examples)

(1) 

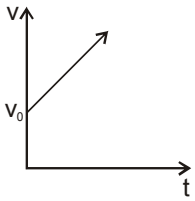
Body is always at rest.

(2) 

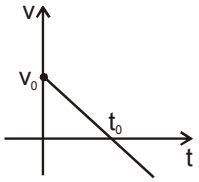
Body is moving with constant velocity v_0

(3) 

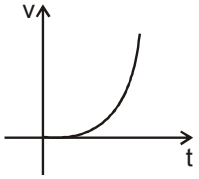
Body is at rest initially then it starts moving with its velocity increasing at a constant rate i.e. body is moving with constant acceleration.

(4) 

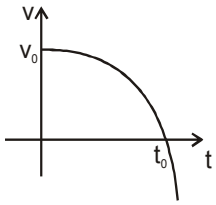
Body starts its motion with initial velocity v_0 and continues to move with its velocity increasing at a constant rate i.e. acceleration of the body is constant.

(5) 

Body starts its motion with initial velocity v_0. Then it continues to move with its velocity decreasing at a constant rate i.e. acceleration of the body is negative and constant. At $t = t_0$ the body comes to rest instantaneously and reverses its direction of motion and then continues to move with decreasing velocity or increasing speed.
For $0 < t < t_0$ motion of the body is decelerated ($\therefore$ speed is decreasing)
$t > t_0$ motion of the body is accelerated ($\therefore$ speed is increasing)

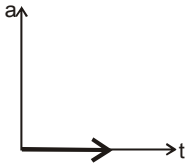
(6) 

Body is at rest initially. Then it starts moving with increasing velocity. As time increases its velocity is increasing more rapidly. i.e. the moving with increasing acceleration.

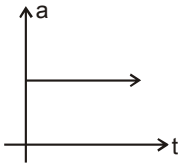
(7) 

Body starts its motion with initial velocity v_0. Its velocity is decreasing with time and at $t = t_0$. It becomes zero after body reverse its direction of motion and continues to move with decreasing velocity or increasing speed. Since velocity of the body is decreasing for whole motion. Therefore, its acceleration is negative.For $0 < t < t_0$ motion of the body is decelerated (speed is decreasing) $t > t_0$ motion of the body is accelerated ($\because$ speed is increasing)

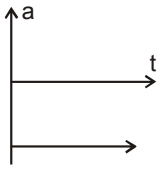
ACCELERATION TIME GRAPH

(1) 

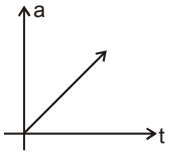
acceleration of the body is zero that means the body is moving constant velocity.

(2) 

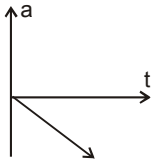
Acceleration of the body is constant and positive.

(3) 

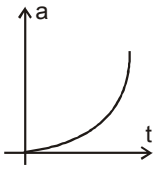
Acceleration of the body is constant and negative

(4) 

Initially the acceleration of the body is zero. Then its acceleration is increasing at a constant rate.

(5) 

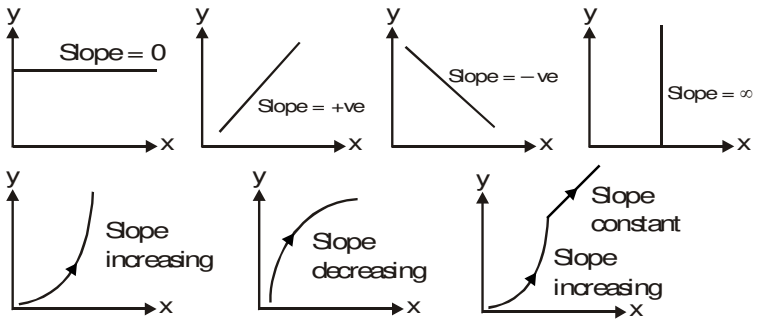
The body starts accelerating(initial acceleration zero) at t = 0. Its acceleration is negative for whole of its motion and is decreasing at a constant rate.

(6) 

Initially acceleration of the body is zero. Its acceleration is positive for whole of its motion. Its acceleration is increasing for whole of its motion.

COMPETITIVE WINDOW

Nature of Slope:-



Newton's Thought

Two cars moving on straight sections of a highway. The acceleration of the first car A is greater than the acceleration of the second car B and both accelerations have the same direction. Which one of the following is true? (a) The velocity of the first car is always greater than the velocity of the second car. (b) The velocity of the second car is always greater than the velocity of the first car. (c) In the same time interval, the velocity of the first car changes by a greater amount than the velocity of the second car does. (d) In the same time interval, the velocity of the second car changes by a greater amount than the velocity of the first car does.

Explanation

Option (c) is true because the acceleration of the first car is greater than the acceleration of the second car, thus in the same time interval, the velocity of the first car changes by a greater amount that the velocity of the second car does.

Option (d) is reverse of option (c), thus it cannot be true simultaneously. It is therefore, a false statement.

Option (a) is false because initial velocity of car A may be less than the velocity of car B. After a certain time interval, velocity of A will become more than the velocity of B.

Option (b) is also false because initial velocity of car A may be less or more than the velocity of car B. Even if the initial velocity of car B is more than velocity of car A, after a certain time interval it will become less than that of car A.

EQUATIONS OF MOTION – GRAPHICAL METHOD

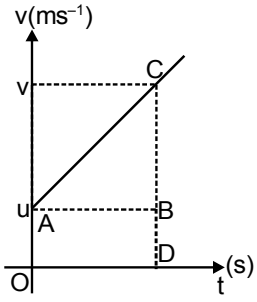
I. Velocity-time equation

Consider the v – t graph shown for a body having velocity u at t = 0 and v at t seconds.

The acceleration 'a' associated with the motion is given by,

$$a = \text{slope} = \frac{BC}{AB} = \frac{v-u}{t-0} = \frac{v-u}{t}$$

$\therefore v - u = at$ or $v = u + at$



II. Position-time equation :

Area below the v – t graph is a measure of the displacement in straight line.

$\therefore$ Displacement s = Area (OACBD)

$$s = \frac{1}{2}(BC \times OD) + OA \times OD = \frac{1}{2}at \times t + ut \quad (\because v - u = at)$$

$$s = ut + \frac{1}{2}at^2$$

III. Position-velocity equations :

Displacement in 't' seconds is given by

$$s = \text{Area of trapezium OACBD} = \frac{1}{2}(OA + CD) \times OD = \frac{1}{2}(u + v) \times t$$

$$s = \frac{1}{2}(u + v) \times \left(\frac{v-u}{a}\right) = \frac{v^2 - u^2}{2a}$$

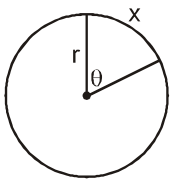
$\therefore v^2 - u^2 = 2as \quad \Rightarrow \quad v^2 = u^2 + 2as$

CIRCULAR MOTION

Motion in a circular path is called circular motion. It is of two kinds – uniform or non- uniform. If the speed of motion is same in the circular path, the motion is called uniform circular motion. If the speed varies – may increase or decrease, then it is non-uniform circular motion.

In a circular motion of radius r,

(i) Angular displacement $\theta = \frac{\text{arc length}}{\text{radius}} = \frac{x}{r}$



(ii) Angular velocity $\omega = \frac{\theta_f - \theta_i}{t}$

(iii) Linear velocity v = radius × angular velocity

$v = r\omega$

(iv) Angular acceleration $\alpha = \frac{\omega_f - \omega_i}{t}$

(v) Linear acceleration a = radius × angular acceleration

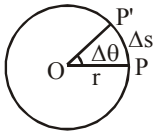
(v) Linear acceleration $a = r\alpha$

UNIFORM CIRCULAR MOTION :

(i) If the radius vector sweeps out equal angles in equal times, then its motion is said to be uniform circular motion.

(ii) In uniform circular motion speed remains const.

(iii) Linear velocity, being a vector quantity, its direction changes continuously.



(iv)The direction of velocity is along the tangent at every point.

◈ **Angular displacement :**

In a circular motion, the angle subtended at the centre by any arc of the circular path of motion is called the angular displacement (θ). It is measured in radians. One radian is that angular displacement whose are length is equal to the radius of the circle.

◈ **Angular velocity :**

The angular displacement of any moving object per second is called its angular velocity (ω).

Angular velocity (ω) = $\frac{\text{Angular displacement}}{\text{Time taken}} \left(\frac{\Delta\theta}{\Delta t}\right)$.

It is expressed in radian per second.

(i) A vector quantity

(ii) Direction is perpendicular to plane of rotation

Note : If the particle is revolving in the clockwise direction then the direction of angular velocity is perpendicular to the plane downwards. Whereas in case of anticlockwise direction the direction will be upwards.

(iii) Unit is Radian/sec.

(iv) In uniform circular motion the direction of angular velocity is along the axis of rotation which is constant throughout.

(v) Angular velocity remains constant in magnitude as well as in direction.

(vi) $v = r\omega$ where r = radius of the circle.

◈ **Angular acceleration :**

The change in angular velocity in unit time is called the angular acceleration (α).

$$\text{Angular acceleration} = \frac{\text{Change in angular velocity}}{\text{Time taken}}$$

(i) Acceleration in a uniform circular motion is directed towards the centre and the direction of velocity at any instant is given by the tangent at that point.

(ii) Since the acceleration is always directed towards the centre in a uniform circular motion, it is an example of variable acceleration even through the magnitude of acceleration is the same.

◈ **Centripetal acceleration :**

(i) In uniform circular motion the particle experiences an acceleration called the centripetal acceleration.

(ii) $\boxed{a_c = \frac{v^2}{r}}$

(iii) The direction of centripetal acceleration is along the radius towards the centre.

◈ **Centripetal force :**

(i) Always acts towards centre.

(ii) Centripetal force is required to move a particle in a circle.

(iii) Because F_c is always perpendicular to velocity or displacement, hence the work done by this force will always be zero.

Note :

(i) Circular motion in horizontal plane is usually uniform circular motion.

(ii) Remember that equations of motion are not applicable for circular motion.

◈ **Time period :**

(i) It is the time taken to complete one complete revolution.

(ii) In one revolution, angle subtended is 2π and if T is time period, then the angular velocity is given by

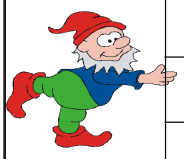
$\boxed{\omega = \frac{2\pi}{T}}$ or $\boxed{T = \frac{2\pi}{\omega}}$

◈ **Frequency :**

(i) Frequency is defined as the no. of revolutions per second.

i.e. $\boxed{n = \frac{1}{T} = \frac{\omega}{2\pi}}$

DO YOU KNOW ?



If on X-axis	& on Y-axis	then Slope	Formula	
Time	Displacement	Velocity	$\vec{v} = \frac{d\vec{s}}{dt}$	$\vec{v}_{av} = \frac{\vec{s}_f - \vec{s}_i}{\text{time}}$
Time	Velocity	Acceleration	$\vec{a} = \frac{d\vec{v}}{dt}$	$\vec{a}_{av} = \frac{\vec{v}_f - \vec{v}_i}{\text{time}}$
Time	Momentum	Force	$\vec{F} = \frac{d\vec{p}}{dt}$	$P_{av} = \frac{W}{\text{time}}$
Time	Energy	Power	$P = \frac{dW}{dt}$	$\vec{\tau}_{av} = \frac{\vec{J}_f - \vec{J}_i}{\text{time}}$

SOLVED PROBLEMS

Ex.1 An object has moved through a distance. Can it have zero displacement ? If yes, support you answer with an example.

Sol. Yes, an object which has moved through a distance can have zero displacement.

Example : When a person, walking along a circular path, returns back to the starting point, after completing a circle, his displacement is zero. But he covers a distance $2\pi r$ where 'r' is the radius of circular path.

The displacement is zero, as the shortest distance between the initial and final position of the person is zero.

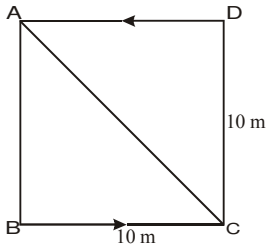
Ex.2 A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds ?

Sol. The perimeter square field ABCD = 4 × 10m = 40 m.

Time for moving around the 10 m square field once = 40 s.

Time for journey of farmer = 2 min and 20 s = 140 s.

Number of times the farmer moves around the square field = $\frac{140}{40} = 3.5$ times.



For going once around the square field, the displacement = 0

For going thrice around the square field, the displacement = 0

For going $\frac{1}{2}$ times the square field, the distance covered = 40 m × $\frac{1}{2}$ = 20 m.

It is obvious from the figure, that if the farmer starts from pt A, then he will cover 10 m along AB and then10 m along BC.

Therefore displacement of farmer from the point A to point C is

$$AC = \sqrt{(AB)^2 + (BC)^2} = \sqrt{(10)^2 + (10)^2} = 14.14 \text{ m}$$

Ex.3 Which of the following is true for displacement ?

(a) It cannot be zero.

(b) Its magnitude is greater than the distance travelled by the object.

Sol. None of the statement (a) or (b) is true for displacement.

Ex.4 Distinguish between speed and velocity.

Sol. (i) Speed is the rate of change of motion but velocity is the rate of change of motion in a specified direction.

(ii) Speed is a scalar quantity, but velocity is a vector quantity.

Ex.5 Under what condition is the magnitude of average velocity of an object equal to its average speed?

Sol. The magnitude of average velocity of an object is equal to its average speed when the velocity of an object changes at uniform rate, i.e., the body is in uniformly accelerated motion. If a body is moving with uniform acceleration.

Initial velocity = u, Final velocity = v, Average speed = Average velocity = $\frac{u+v}{2}$.

SPEED

Speed of a body is the distance travelled by the body per unit time. or The rate of change of motion is called speed.

$$\boxed{\text{Speed} = \frac{\text{distance travelled}}{\text{time taken}}}$$

If a body covers a distance S in time t then speed,

$$\boxed{v = \frac{S}{t}}$$

Ex.6 What does speedometer of an automobile measure ?

Sol. The speedometer measures the instantaneous speed of the automobile at some particular time.

Ex.7 What does the path of an object look like when it is in uniform motion ?

Sol. The path of an object will be a straight line.

Ex.8 During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station ? The signal travels at the speed of light, that is 3×10^8 ms^{-1}.

Sol. Speed of signal = 3×10^8 ms^{-1}

Time in which signal reaches ground = 5 min = $5 \times 60 = 300$ s

Distance of spaceship from the ground level = speed × time = $3 \times 10^8 \times 300 = 9 \times 10^{10}$ m

Ex.9 When will you say a body is in

(i) Uniform acceleration.

(ii) Non uniform acceleration ?

Sol. (i) A body is in uniform acceleration when equal changes in velocity take place in equal intervals of time,however small these intervals may be.

(ii) A body is said to be possessing non-uniform acceleration when unequal changes in velocity take place in equal intervals of time, however small these intervals may be.

Ex.10 A bus decreases its speed from 80 km h^{-1} to 60 km h^{-1} in 5 s. Find the acceleration of the bus.

Sol. Given t = 5 s

Initial speed of bus

$$u = 80 \text{ km h}^{-1} = 80 \times \frac{5}{18} = 22.2 \text{ ms}^{-1}$$

Final speed of the bus

$$v = 60 \text{ km h}^{-1} = 60 \times \frac{5}{18} = 16.7 \text{ ms}^{-1}$$

Now acceleration is given by the relation

$$a = \frac{v - u}{t} = \frac{16.7 - 22.2}{5} = -1.1 \text{ ms}^{-1}$$

Ex.11 A train starting from a railway station and moving with uniform acceleration attains a speed 40 kmh^{-1} in 10 minutes. Find its acceleration.

Sol. Given t = 10 min = $10 \times 60 = 600$ s

Initial speed of train, u = 0 ms^{-1}

Final speed of train

$$v = 40 \text{ km h}^{-1} = 40 \times \frac{5}{18} = 11.1 \text{ ms}^{-1}$$

Now acceleration is given by the relation

$$a = \frac{v - u}{t} = \frac{11.1 - 0}{600} = 0.0185 \text{ ms}^{-1}$$

Ex.12 What is the nature of the distance time graphs for uniform and non-uniform motion of an object ?

Sol. The distance time-graph for uniform motion is a straight line not parallel to the time axis. The distance time-graph for non-uniform motion is not a straight line. It can be a curve or a zigzag line not parallel to time axis.

Ex.13 What can you say about the motion of an object whose distance time-graph is a straight line parallel to the time axis ?

Sol. The object is stationary.

Ex.14 What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis ?

Sol. The object has uniform speed.

Ex.15 What is the quantity which is measured by the area occupied below the velocity-time graph ?

Sol. Displacement is the quantity which is measured by the area under velocity time graph.

Ex.16 A bus starting from rest moves with a uniform acceleration of 0.1 ms^{-2} for 2 minutes. Find
(a) the speed acquired. (b) the distance travelled.

Sol. Given
Initial speed of bus, u = 0 ms^{-1}
Final speed of bus, v = ?
a = 0.1 ms^{-2}, t = 2 min = 120 s
S = ?

(i) We know, $v = u + at$
or $v = 0 + 0.1 \times 120 = 12\ ms^{-1}$

(ii) $S = ut + \frac{1}{2}at^2$

$S = 0 \times 120 + \frac{1}{2} \times 0.1 \times (120)^2 = 720$ m

Therefore
Final speed acquired = 12 ms^{-1}
Distance travelled = 720 m

Ex.17 A train is travelling at a speed of 90 kmh^{-1}. Brakes are applied so as to produce a uniform acceleration of – 0.5 ms^{-2}. Find how far the train will go before it is brought to rest.

Sol. Given
Initial speed of train,

$u = 90\ km\ h^{-1} = 90 \times \frac{5}{18} = 25\ ms^{-1}$

Final speed, v = 0 ms^{-1}

Acceleration a = – 0.5 ms^{-2}

Distance covered, S = ?

Using the relation $v^2 - u^2 = 2aS$, we have

$$S + \frac{v^2 - u^2}{2a} = \frac{0 - (25)^2}{2 \times (-0.5)} = 625\ m$$

Ex.18 A trolley, while going down an inclined plane, has an acceleration of 2 cms^{-2}. What will be its velocity 3 s after the start ?

Sol. Given

Initial velocity, u = 0

Final velocity, v = ?

Time, t = 3 s

Acceleration, a = 2 cms^{-2}

We know that v = u + at

Or $v = 0 + 2 \times 3 = 6\ cms^{-1}$

Therefore, final velocity = 6 cms^{-1}.

Ex.19 A racing car has uniform acceleration of 4 ms^{-2}. What distance will it cover in 10 s after start.

Sol. Given

Initial velocity, u = 0

Acceleration, a = 4 ms^{-2}

Time, t = 10 s

Distance covered, S = ?

We know ; $S = ut + \frac{1}{2}at^2$

$S = 0 \times 10 + \frac{1}{2} \times 4 \times (10)^2$

= 0 + 200 = 200 m

Therefore, distance covered = 200 m.

Ex.20 A stone is thrown in a vertically upward direction with a velocity of 5 ms^{-1}. If the acceleration of the stone during its motion is 10 ms^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there ?

Sol. Given

Initial velocity, u = 5 ms^{-1}

Final velocity, v= 0

Acceleration in the downward direction = 10 ms^{-2}

Therefore acceleration in the upward direction

a = – 10 ms^{-2}

Height attained by stone, S = ?

Time taken to attain height, t = ?

(i) Using the relation ; v = u + at

0 = 5 + (– 10) t or

t = 5/10 = 0.5 s

(ii) Using the relation ; $v^2 - u^2 = 2aS$, we have

$$S = \frac{v^2 - u^2}{2a} = \frac{(0)^2 - (5)^2}{2 \times (-10)} = 1.25 \text{ m}$$

Ex.21 An artificial satellite is moving in a circular oribit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth.

Sol. R = 42250 km.

t = 24 hrs.

v = ?

$$V = \frac{2\pi r}{t} = \frac{2\pi \times 42250}{24}$$

v = 3.07 km/sec.

NCERT QUESTIONS WITH SOLUTIONS

Q.1 An athlete completes one round. of a circular track of diameter 200 m in 40 s. What will be the distance covered and the displacement at the end of 2 minutes 20 s?

Ans. Given

Diameter of circular track, 2r =200 m

Circumference of circular track = $2\pi r$

$$s = \pi(2r) = \frac{22}{7} \times 200 = \frac{4400}{7} m$$

Time for completing one round = 40 s.

Time for which the athlete ran =2 min and 20 s = 140s

$$s = \frac{4400}{7} m \ \therefore \text{ Distance covered in 1s} = \frac{4400}{7 \times 40} m$$

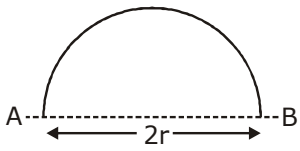
(i) Therefore, distance covered by athlete in 140s $= \frac{4400}{7} \times \frac{140}{40} = 2200m$

(ii) As the athlete returns to the initial point in 40s, his displacement = 0

Now,

Number of rounds in 40 seconds = 1

Hence number of rounds in 140s is $= \frac{140}{40} = 3\frac{1}{2}$.



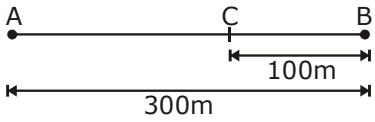
For each complete round the displacement is zero. Therefore for 3 complete rounds, the displacement will be zero.

The final displacement will be due to half the round (i.e. semicircle).

Thus, his displacement = diameter of circular track = 200 m.

Q.2 Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 50 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging (a) from A to B and (b) from A to C?

Ans. The required figure is as shown



(a) Distance covered = 300m

Time taken = 2 min and 50s = 170 s

Now average speed from A to B is given by

$$V_{av} = \frac{\text{distance covered}}{\text{time}} = \frac{300}{170} = 1.76 ms^{-1}$$

Now average velocity from A to B is given by

$$V_{av} = \frac{\text{displacement}}{\text{time}} = \frac{300}{170} = 1.76 ms^{-1}$$

(b) When Joseph turns around from B to C towards west, then

Distance covered = 300 + 100 = 400 m

Time taken = 170 + 60 = 230s

Therefore, average speed from A to C is

$$V_{av} = \frac{\text{distance covered}}{\text{time}} = \frac{400}{230} = 1.74\,ms^{-1}$$

Now displacement from A to C = 200m

Therefore, average velocity from A to C is

$$V_{av} = \frac{\text{displacement}}{\text{time}} = \frac{200}{230} = 0.869\,ms^{-1}$$

Q.3 Abdul while driving to school computes the average speed for his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 40 km h^{-1}. What is the average speed for Abdul's trip?

Ans. Let one way distance for his trip be s.

Let t_1 be the time for his trip from home to school and t_2 be the time for his return trip.

Then $t_1 = \frac{S}{v_1} = \frac{S}{20}h$, and $t_2 = \frac{S}{v_2} = \frac{S}{40}h$

Therefore, total time of trip is

$$T = t_1 + t_2 = \frac{S}{20} + \frac{S}{40} = \frac{3S}{40}h$$

Total distance covered = 2S

Therefore, average speed of Abdul

$$V_{av} = \frac{\text{total distance}}{\text{total time}} = \frac{2S \times 40}{3S} = 26.6\ kmh^{-1}$$

Q.4 A motorboat starting from rest on a lake accelerates in a straight line at a constant rate or 3.0 ms^{-2} for 8.0 s. Hew far does the boat travel during this time?

Ans. Given, initial velocity of boat, u = 0

Acceleration, a = 3.0 m s^{-2}

Time, t = 8s

Distance covered, s = ?

Using the relation $s = ut + \frac{1}{2}at^2$ we have,

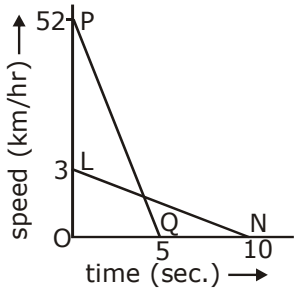
$s = 0 \times 8 + \frac{1}{2} \times 3 \times 8^2 = 96m.$

Q.5 The driver of a car travelling at 52 km h^{-1} applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5s. Another driver going at 3 kmh^{-1} in another car applies his brakes slowly and stops in 10s. On the same graph paper, plot the speed versus time graphs for the two cars. Which of the two cars travelled father after the brakes were applied?

Ans. The speed time graph of both the cars are shown below.

(i) Distance covered by car moving at 52 kmh^{-1} (or $52 \times \frac{5}{18} = 14.4\ ms^{-1}$)

= area of $\Delta PQR = \frac{1}{2} \times PO \times OQ = \frac{1}{2} \times 14.4 \times 5 = 36$ m



(ii) Distance covered by car moving at 3 kmh^{-1} (or $3 \times \frac{5}{18} = 0.83\ ms^{-1}$)

= area of $\Delta PLN = \frac{1}{2} \times LO \times ON = \frac{1}{2} \times 0.83 \times 10 = 4.15$ m

$\therefore$ The car moving at 52 km h^{-1} travels more distance on the application of brakes.

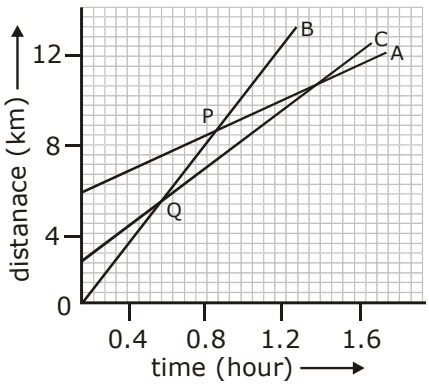
Q.6 Figure below shows the distance-time graph of three objects A, Band C. Study the graph and answer the following questions:

(a) Which of the three is travelling the. fastest?

(b) Are all three ever at the same point on the road?

(c) How far has C travelled when B passes A ?

(d) How far has B travelled by the time it passes C ?



Ans. (a) Car B is travelling the fastest, because its slope is largest among the three.

(b) No, they are never at the same point because aU the graphs of A, Band C do not intersect at one point.

(c) When car B passes car A at point P, the distance covered by car C = 8 – 2 = 6 km. (approx.)

(d) Car B and C pass each other at point Q. The distance travelled by B at that point is nearly 5.7 km.

Q.7 A ball is gently dropped from a height of 20 m. If its velocity Increases uniformly at the rate of 10 ms^{-2}, with what velocity will it strike the ground? After what time will it strike the ground? .

Ans. Given, initial velocity of ball, u = 0

Final velocity of ball, v = ?

Distance through which the ball falls, s = 20 m

Acceleration a = 10 ms^{-2}

Time of fall, t = ?

We know

$v^2 - u^2 = 2as$

or $v^2 - 0 = 2 \times 10 \times 20 = 400$ or $v = 20\ ms^{-1}$

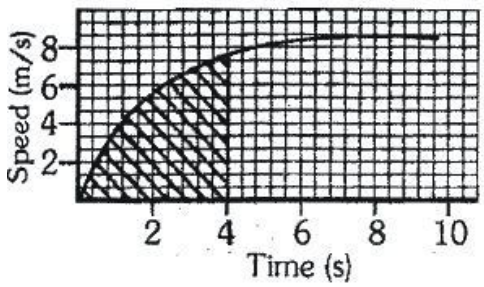
Now using $v = u + at$ we have

$20 = 0 + 10 \times t$ or $t = 2s$

Q.8 The speed-time graph for a car is shown in figure below.

(a) Shade the area on the graph that represents the distance travelled by the car during the first 4 seconds.

(b) Which part of the graph represents uniform motion of the car?



Ans. (a) During first 4 seconds, car is moving with nonuniform acceleration. Area of shaded portion represents distance travelled.

(b) The straight line portion of the graph represents uniform motion of the car.

Q.9 State which of the following situations are possible and give an example for each of these;

(a) An object with a constant acceleration but with zero velocity.

(b) An object moving in a certain direction with acceleration in the perpendicular direction.

Ans. (a) A body with a constant acceleration but with zero velocity is possible. For example, when a body is just released, its initial velocity u = 0, but acceleration g = 10 ms^{-2}.

(b) It is possible. When a stone, tied to a string, is whirled in a circular path, the acceleration acting on it is always at right angle to the direction of motion of stone.

Q.10 An artificial satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth.

Ans. Distance covered by the satellite in 24 hours

$S = 2\pi r$

$$= 2 \times \frac{22}{7} \times 42250 = 265571.43\,km$$

Therefore speed of satellite

$$v = \frac{\text{distance travelled}}{\text{time taken}} = \frac{265571.43}{24 \times 60 \times 60} = 3.07\,kms^{-1}$$

EXERCISE – I BOARD PROBLEMS

Q.1 Distinguish between speed and velocity.

Q.2 What does the path of an object look like when it is in uniform motion?

Q.3 Under what condition will the displacement and distance have the same magnitude?

Q.4 A boy hits a football high up into the air. He runs and catches the foot ball before it hits the ground. Which of the two, the boy or the football has had greater displacement?

Q.5 Can the speed of a body be negative?

Q.6 What is the average velocity of particle when it returns to the starting point ? Can its average speed by zero?

Q.7 A car manufacturer advertises that the brakes are so perfect that the car stops instantaneous. Comment.

Q.8 Give an example of a body which covers a certain distance, but its displacement is zero?

Q.9 Can the displacement of a particle be zero when the distance travelled is not zero?

Q.10 What is the relation between distance and time

(i) when body is moving with uniform speed?

(ii) when body is moving with variable speed?

Q.11 Draw velocity-time graphs for the following situations :

(i) When body is moving with uniform velocity.

(ii) When body is moving with variable velocity, but uniform acceleration

(iii) When body is moving with variable velocity, but uniform retardation

(iv) When body is moving with variable velocity and variable acceleration

Q.12 Distinguish between terms distance and displacement.

Q.13 Mention some uses of velocity time graphs.

Q.14 A train starting from a railway station and moving with uniform acceleration attains a speed 40 km h^{-1} in 10 minutes. Find its acceleration.

Q.15 A bus starting from rest moves with a uniform acceleration of 0.1 ms–2 for 2 minutes. Find (a) the speed acquired,

(b) the distance travelled.

Q.16 A driver of a car travelling at 52 kmh^{-1} applies the brakes and accelerates uniformly in the opposite direction. The car stops in 5s. Another driving going at 3 kmh^{-1} in another car applies his brakes slowly and stops in 10s. On the same graph paper, plot the speed versus time graphs for the two cars. Which the two cars travelled farther after the brakes were applied.

Q.17 A train is travelling at a speed of 90 kmh^{-1}. Brakes are applied so as to produce a uniform acceleration of – 0.5 ms^{-2}. Find how far the train will go before it is brought to rest.

Q.18 An athlete completes one round of a circular track of diameter 200m in 40s. What will be the distance covered and the displacement at the end of 2 minutes 20 s?

Q.19 An aeroplane lands at 216 kmh^{-1} and stops after covering a runway of 2km. Calculate the acceleration and the time, in which it comes to rest.

Q.20 A truck running at 90 kmh^{-1} is brought to rest over a distance of 25m. Calculate the retardation and time for which brakes are applied.

Q.21 A motor bike running to 90 kmh^{-1}, is slowed down to 54 kmh^{-1} by the application of brakes, over a distance of 40m. If the brakes are applied with the same force, calculate (i) total time in which bike comes to rest (ii) total distance travelled by bike.

Q.22 A person travels a distance of 5 m towards east, then 4 m towards north and then 2 m towards west.

(i) Calculate the total distance travelled.

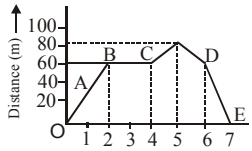
(ii) Calculate the resultant displacement.

Q.23 A body is moving in a straight line. Its distances from origin are shown with time in Fig. A, B, C, D and E represent different parts of its motion. Find the following :

(i)Displacement of the body in first 2 seconds.

(ii) Total distance travelled in 7 seconds.

(iii) Displacement in 7 seconds



Distance-time graph

Q.24 The distance between two points A and B is 100 m. A person moves from A to B with a speed of 20 m/s and from B to A with a speed of 25 m/s. Calculate average speed and average velocity.

Q.25 A car moves with a speed of 40 km/hr for first hour, then with a speed of 60 km/hr for next half hour and finally with a speed of 30 km/hr for next $1\frac{1}{2}$ hours. Calculate the average speed of the car.

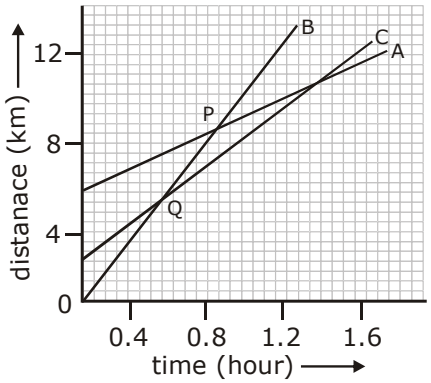
Q.26 Figure below shows the distance-time graph of three objects A, Band C. Study the graph and answer the following questions:

(a) Which of the three is travelling the. fast-est?

(b) Are all three ever at the same point on the road?

(c) How far has C travelled when B passes A ?

(d) How far has B travelled by the time it passes C ?



Q.27 A bus starting from rest moves with a uniform acceleration of 0.1 ms^{-2} for 2 minutes. Find

(a) the speed acquired.

(b) the distance travelled.

Q.28 A train starting from a railway station and moving with uniform acceleration attains a speed 40 kmh^{-1} in 10 minutes. Find its acceleration.

Q.29 From the top of a tower of height 490 m, a shell is fired horizontally with a velocity 100 m/s. At what distance from the bottom of the tower, the shell will hit the ground ?

Q.30 The brakes applied to a car produce a negative acceleration of 6 m/s^2. If the car takes 2 seconds to stop after applying the brakes, calculate the distance it travels during this time.

Q.31 Starting from rest, Deepak paddles his bicycle to attain a velocity of 6 m/s in 30 seconds then he applies brakes so that the velocity of the bicycle comes down to

4 m/s in the next 5 seconds. Calculate the acceleration of the bicycle in both the cases.

Q.32 A body starts moving with an initial velocity 50 m/s and acceleration 20 m/s^2. How much distance it will cover in 4s ? Also, calculate its average speed during this time interval.

Q.33 A body is moving with a speed of 20 m/s. When certain force is applied, an acceleration of 4 m/s^2 is produced. After how much time its velocity will be 80 m/s ?

Q.34 A body starts from rest and moves with a constant acceleration. It travels a distance s_1 in first 10 s, and a distance s_2 in next 10 s. Find the relation between s_2 and s_1.

Q.35 A train is moving with a velocity 400 m/s. With the application of brakes a retardation of 10 m/s^2 is produced. Calculate the following :

(i) After how much time it will stop ?

(ii) How much distance will it travel before it stops?

Q.36 A body is thrown vertically upwards with an initial velocity of 19.6 m/s. If g = –9.8 m/s^2. Calculate the following :

(i) The maximum height attained by the body.

(ii) After how much time will it come back to the ground ?

EXERCISE – II OLYMPIAD QUESTIONS

Q.1 A body goes from A to B with a velocity of 20 m/s and comes back B to A with a velocity of 30 m/s. The average velocity of the body during the whole journey is
(A) zero (C) 25 m/s
(B) 24 m/s (D) none of these

Q.2 If an object covering distances in direct proportion to the square of the time lapsed, then the acceleration is
(A) increasing (B) decreasing
(C) constant (D) none of these

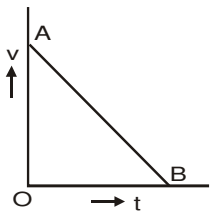
Q.3 Distance travelled by a freely falling body is proportional to :-
(A) mass of the body
(B) square of the acceleration due to gravity
(C) square of the time of fall
(D) time of fall

Q.4 The rate of change of displacement with time is :-
(A) speed (B) acceleration
(C) retardation (D) velocity

Q.5 Which of the following is not vector quantity?
(A) Retardation
(B) Acceleration due to gravity
(C) Average speed
(D) Displacement

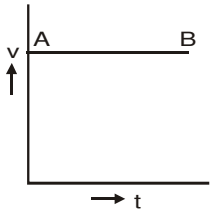
Q.6 If the time-displacement graph of a particle is parallel to the time-axis, then velocity of the particle is :-
(A) infinity
(B) unity
(C) equal to acceleration of the body
(D) zero

Q.7 In the velocity-time graph, AB shows that the body has :-



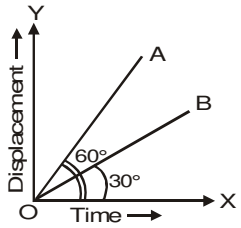
(A) uniform acceleration
(B) non-uniform retardation
(C) uniform speed
(D) initial velocity OA and is moving with uniform retardation

Q.8 In the given velocity-time graph, AB shows that the body has



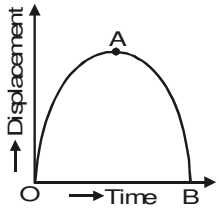
(A) uniform acceleration
(B) uniform retardation
(C) uniform velocity throughout its motion and has zero initial velocity
(D) none of these

Q.9 If the displacement-time graph for the two particles A and B are straight lines inclined at angles of 30° and 60° with the time axis, then ratio of the velocities v_A: v_B will be



(A) 1 : 2 (B) 1 : 3
(C) $\sqrt{3}$: 1 (D) 3: 1

Q.10 In the given figure, velocity of the body at A is



(A) zero (B) unity
(C) maximum (D) infinite

Q.11 The velocity-time graph for a body with nonuniform motion is a
(A) curved line
(B) straight line parallel to x-axis
(C) straight line parallel to y-axis
(D) none of these

Q.12 Area under a velocity-time graph gives
(A) time taken by a moving object
(B) distance travelled by a moving object
(C) acceleration of moving object
(D) retardation of a moving object

Q.13 If a body is thrown up with an initial velocity u and covers a maximum height of h, then h is equal to :-

(A) $\frac{u^2}{2g}$ (B) $\frac{u}{2g}$

(C) $2u^2g$ (D) None of these

Q.14 A body is thrown vertically upwards and rises to a height of 10m. The velocity with which the body was thrown upwards is (g = 9.8 m/s^2)
(A) 16 m/s (B) 15 m/s
(C) 14 m/s (D) 12 m/s

Q.15 A truck running along a straight line increases its speed uniformly from 30 m/s to 60 m/s over a time interval 1 min. The distance travelled during this time interval is
(A) 900 m (B) 1800 m
(C) 2700 m (D) 3600m

Q.16 A car travels $\frac{1}{3}$rd distance on a straight road with a velocity of 10 km/hr, next $\frac{1}{3}$rd with velocity 20 km/hr and the last $\frac{1}{3}$rd with velocity 60 km/hr. What is the average velocity of the car in the whole journey?
(A) 4 km/hr (B) 6 km/hr
(C) 12 km/hr (D) 18 km/hr

Q.17 A motor ship covers the distance of 300 km between two localities on a river in 10 hrs downstream and in 12 hrs upstream. Find the flow velocity of the river assuming that these velocities are constant.
(A) 2.0 km/hr (B) 2.5 km/hr
(C) 3 km/hr (D) 3.5 km/hr

Q.18 Driver of a train travelling at 115 km/hr sees on a same track, 100m infront of him, a slow train travelling in the same direction at 25 km/hr. The least retardation that must be applied to faster train to avoid a collision is
(A) 3.125 m/s^2 (B) 3.5 m/s^2
(C) 2.75 m/s^2 (D) 3.0 m/s^2

Q.19 Distance of the moon from the earth is 4×10^8 m. The time taken by a radar signal transmitted from the earth to reach the moon is
(A) 5.2 s (B) 1.3 s
(C) 2.6 s (D) 0.70 s

Q.20 A stone is dropped into a well in which the level of water is h, below the top of the well. If v is velocity of sound, then time T after which the splash is heard is equal to

(A) $\frac{2h}{v}$ (B) $\sqrt{\frac{2h}{v}}+\frac{h}{g}$

(C) $\sqrt{\frac{2h}{g}}+\frac{h}{v}$ (D) $\sqrt{\frac{h}{2g}}+\frac{2h}{v}$

Q.21 A stone weighing 3 kg falls from the top of a tower 100 m high and buries itself 2 m deep in the sand. The time of penetration is :-
(A) 0.09 sec (B) 0.9 sec
(C) 2.1 sec (D) 1.3 sec

Q.22 The velocity of a body at any instant is 10 m/s. After 5 sec, velocity of the particle is 20 m/s. The velocity at 3 seconds before is
(A) 8 m/sec (B) 4 m/sec
(C) 6 m/sec (D) 7 m/sec

Q.23 A body covers 200 cm in the first 2 sec.and 220 cm in next 4 sec. What is the velocity of the body at the' end of 7th second?
(A) 40 cm/sec (B) 20 cm/sec
(C) 10 cm/sec (D) 5 cm/sec

Q.24 If two bodies of different masses m_1 and m_2 are dropped from different heights h_1 and h_2, then ratio of the times taken by the two to drop through these distances is :-
(A) $h_1 : h_2$ (B) h_2/h_1
(C) $\sqrt{h_1} : \sqrt{h_2}$ (D) $h_1^2 : h_2^2$

Q.25 Name the instrument used to measure instantaneous speed of a vehicle:
(A) Accelerator (B) Speedometer
(C) Ammeter (D) Multicenter

Q.26 A ball is dropped on the floor from a height of 10 m. It rebounds to a height of 2.5 m. If the ball is in contact with the floor for 0.01 sec, then average acceleration during contact is :-
(A) 2100 m/s^2 (B) 1400 m/s^2
(C) 700 m/s^2 (D) 400 m/s^2

Q.27 A stone is thrown vertically upward with an initial velocity u from the top of a tower, reaches the ground with a velocity 3u. The height of the tower is :-

(A) $\frac{3u^2}{g}$ (B) $\frac{4u^2}{g}$

(C) $\frac{6u^2}{g}$ (D) $\frac{9u^2}{g}$

Q.28 If a ball is thrown up with a certain velocity. It attains a height of 40 m and comes back to the thrower, then :-

(A) total distance covered by it is 40 m
(B) total displacement covered by it is 80 m
(C) total displacement is zero
(D) total distance covered by it is zero

Q.29 Acceleration of a body projected upwards with a certain velocity is

(A) 9.8 m/s^2 (B) – 9.8 m/s^2
(C) zero (D) insufficient data

Q.30 If a body of mass 0.10 kg is moving on circular path of diameter 1.0 m at the rate of 10 revolutions per 31.4 sec, then centripetal force acting on the body (n = 3.14) is

(A) 0.2 Newton (B) 2.0 Newton
(C) 0.02 Newton (D) 20.0 Newton

Q.31 The earth's radius is 6400 km. It makes one revolution about its own axis in 24 hrs. The centripetal acceleration of a point on its equator is nearly

(A) 340 cm/s^2 (B) 34 cm/s^2
(C) 3.4 cm/s^2 (D) 0.34 cm/s^2

Q.32 The acceleration of a point on the rim of flywheel 1 m in diameter, if it makes 1200 revolutions per minute is

(A) $8\pi^2$ m/s^2 (B) 80 π^2 m/s^2
(C) 800 π^2 m/s^2 (D) none of these

Q.33 A phonograph record on turn table rotates at 30 rpm. The linear speed of a point on the record at the needle at the beginning of the recording when it is at a distance of 14 cm from the centre is

(A) 22 cm/sec (B) 44 cm/sec
(C) 48 cm/sec (D) 52 cm/sec

Q.34 The relationship between average speed, time and distance is

(A) Average speed = distance × time

(B) Average speed = $\frac{\text{total distance}}{\text{total time}}$

(C) Time = average speed/distance
(D) Distance = average speed × time

Q.35 A body moving along a circular path has
(A) constant speed
(B) constant velocity
(C) no radial acceleration
(D) no tangential velocity

Q.36 A rubber ball dropped from a certain height is an example of
(A) uniform acceleration
(B) uniform retardation
(C) uniform speed
(D) non-uniform speed

Q.37 If the velocity of a body does not change, its acceleration is

(A) zero (B) infinite
(C) unity (D) none of these

Q.38 When the distance an object travels is directly proportional to the length of time, it is said to travel with
(A) zero velocity
(B) constant speed
(C) constant acceleration
(D) uniform velocity

Q.39 A body moves on three quarters of a circle of radius r. The displacement and distance travelled by it are:-
(A) displacement = r, distance = 3r

(B) displacement $\sqrt{2}r$, distance = $\frac{3\pi r}{2}$

(C) distance 2r, displacement = $\frac{3\pi r}{2}$

(D) displacement 0, distance = $\frac{3\pi r}{2}$

Q.40 For the motion on a straight line path with constant acceleration the ratio of the magnitude of the displacement to the distance covered is :-

(A) = 1 (B) ≥ 1
(C) ≤ 1 (D) < 1

Answers

1.	A	**2.**	C	**3.**	C	**4.**	D
5.	C	**6.**	D	**7.**	D	**8.**	D
9.	D	**10.**	A	**11.**	A	**12.**	B
13.	A	**14.**	C	**15.**	C	**16.**	D
17.	B	**18.**	A	**19.**	B	**20.**	C
21.	A	**22.**	B	**23.**	C	**24.**	C
25.	B	**26.**	A	**27.**	B	**28.**	C
29.	B	**30.**	A	**31.**	C	**32.**	C
33.	B	**34.**	B	**35.**	A	**36.**	D
37.	A	**38.**	B	**39.**	B	**40.**	A

EXERCISE – III Multipal Choice Problems

SECTION-A

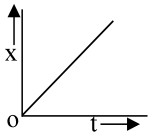
- **Fill in the blanks**

1. A particle moves in a circle of radius R. In half the period of revolution its displacement is _____ and distance covered is _____.

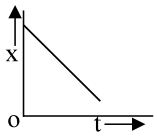
SECTION-B

- **Multiple choice question with one correct answers**

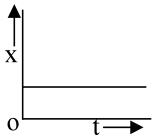
1. Figures show the displacement time graph of a particle moving on the x – axis. Then match the correct order : –

(1) 

(a) Object is at rest

(2) 

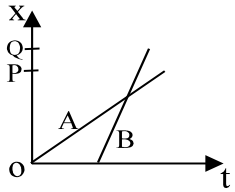
(b) Object moving with positive velocity

(3) 

(c) Object moving with negative velocity

(A) 1 – A, 2 – B, 3 – C (B) 1 – B, 2 – C, 3 – A (C) 1 – C, 2 – B, 3 – A (D) None of these

2. The position time (x– t) graph for two children A and B returning froms their school O to their homes P and Q respectively are shown in fig. choose the correct entries in the brackets below :



(A) (B) lives closer to the school than (A).
(B) (B) starts from the school earlier than (A).
(C) (A) walks faster than (B).
(D) (A/B) overtakes (B/A) on the road (once/twice)

3. A particle has a velocity is towards east at t = o. Its accderation is towards west and is constant. Let x_A and x_B be the magnitude of displacments in the first 10 seconds and the next 10 seconds.
(A) $x_A < x_B$ (B) $x_A = x_B$
(C) $x_A > x_B$
(D) the information is in sufficient to decide the relation of x_A with x_B.

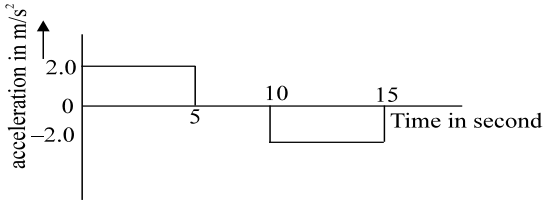
4. A person travelling on a strainght line moves with a uniform velocity v_1 for some time and with uniform velocity v_2 for the next equal time. The average velocity v is given by : –

(A) $v = \frac{v_1 + v_2}{2}$ (B) $v = \sqrt{v_1 v_2}$ (C) $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$ (D) $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$

5. A person travelling on a straight line moves with a uniform velocity v_1 for a distance x and with a uniform velocity v_2 for the next equal distance. The average velocity v is given by : –

(A) $v = \frac{v_1 + v_2}{2}$ (B) $v = \sqrt{v_1 v_2}$ (C) $\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2}$ (D) $\frac{1}{v} = \frac{1}{v_1} + \frac{1}{v_2}$

6. A stone is released from an elevator going up with an acceleration a. The acceleration of the stone after the release is:
   (A) a upward (B) (g – a) upward (C) (g – a) downward (D) g downward
7. A person standing near the edge of the top of a building throws two balls A and B. The ball A is throwns vertically upward and B is thrown vertically downward with the same speed The ball A hits the ground with a speed v_A and the ball B hits the ground with a speed v_B. we have : –
   (A) $V_A > V_B$ (B) $V_A < V_B$ (C) $V_A = V_B$
   (D) the relation between V_A and V_B depends on height of the building above the ground
8. The acceleration of a car started at t = o, varies with times as shown in figure. the distance travelled in 15 seconds is : –



   (A) 100 m (B) 25 m (C) 150 m (D) 0 m
9. A player throws a ball upwards with an initial speed of 29.4 m s^{-1}. The time taken by the ball to return to the player's hands is. (Take g = 9.8 m s^{-2} and neglect air resistance).
   (A) 10 sec (B) 8 sec (C) 12 sec (D) 6 sec
10. A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 km h^{-1}. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 km h^{-1}. the average speed of the man over the interval of time 0 to 40 min.
    (A) 5 km h^{-1} (B) 7.5 km h^{-1} (C) 5.625 km h^{-1} (D) None of these
11. What is the speed with which a stone leaves a string, if it is let go when the length of the string holding the stone is 0.7 m and is revolving at 3 rev/s?
    (A) 15.6 m/s (B) 10.2 m/s (C) 13.2 m/s (D) none of these
12. Ratio of displacment to distance is:
    (A) always < 1 (B) always = 1 (C) always > 1 (D) = or < 1

SECTION-C

- **Assertion & Reason**

  Instructions: In the following questions as Assertion (A) is given followed by a Reason (R). Mark your responses from the following options.

  (A) Both Assertion and Reason are true and Reason is the correct explanation of 'Assertion'
  (B) Both Assertion and Reason are true and Reason is not the correct explanation of 'Assertion'
  (C) Assertion is true but Reason is false
  (D) Assertion is false but Reason is true

1. **Assertion:** The v–t graph perpendicular to the time axis is not possible.
   Reason: If v–t graph is perpendicular to the time axis, then acceleration of the particle should be infinite.
2. **Assertion:** Retardation is directed opposite to the velocity
   Reason: Retardation is equal to the time rate of decrease of speed.
3. **Assertion:** Relative velocity when particles are moving on the same straight line path can be greater in magnitude than velocity of either particle.
   Reason: When the particles are moving with velocities v_1 and v_2 in opposite directions, then relative velocity = $v_1 + v_2$

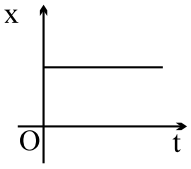
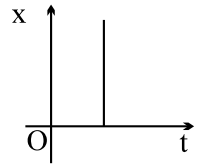
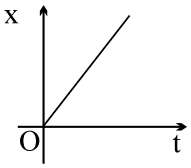
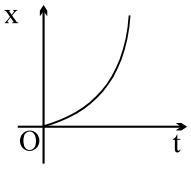
4. **Assertion:** A body can have acceleration even if its velocity is zero at a given instant of time.
   Reason: A body is momentarily at rest when it reverses its direction of motion.
5. **Assertion:** The velocity of a particle may vary even when its speed is constant.
   Reason: Such a body may move along a circular path
6. **Assertion:** The *x*–t graph for a body at rest is a straight line parallel to time axis.
   Reason: A body at rest does not change its position with the lapse of time.

SECTION-D

- **Match the following (one to one)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. Only One entries of column-I may have the matching with the some entries of column-II and one entry of column-II Only one matching with entries of column-I

1.

Column I *(Distance time graph)*	**Column II** *(Type of motion)*
(A) 	(P) Body moves with constant speed
(B) 	(Q) Non-uniform motion
(C) 	(R) Body is stationary
(D) 	(S) Not possible

2.

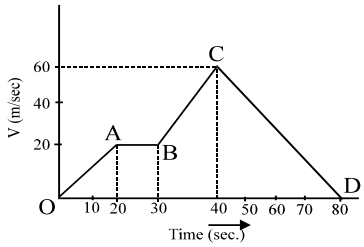
Column I *(Type of motion)*	**Column II** *(Nature of Acceleration)*
(A) Circular Motion	(P) Acceleration is along the direction of motion
(B) Uniform Motion	(Q) Acceleration is along perpendicular direction of the motion.
(C) Free Fall	(R) Acceleration is in the opposite direction of motion
(D) A stone thrown upward with initial velocity 'u'	(S) Acceleration is Zero

EXERCISE – IV Multipal Choice Problems

SECTION-A

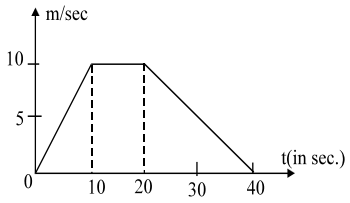
- **Multiple choice question with one correct answers**

1. The following shows the time-velocity graph for a moving object. The maximum acceleration will be-



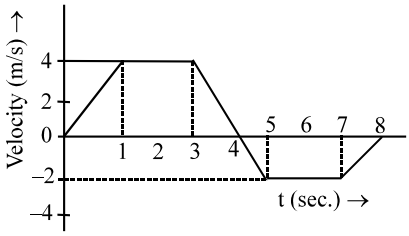
(A) 1 m/sec² (B) 2 m/sec² (C)3m/sec² (D)4m/sec²

2. The adjoining curve represents the velocity time graph of a particle, its acceleration values along OA, AB and BC in m,/sec². are respectively-



(A) 1, 0, –0.5 (B) 1 , 0, 0.5
(C) 1, 1, 0.5 (D) 1, 0.5, 0

3. The v-t graph of a linear motion is shown in adjoining figure. The distance from origin after 8 sec. is-



(A) 18 meters (B) 16 meters
(C) 8 meters (D) 6 meters

4. A motor car covers 1/3 part of total distance with v_1 = 10 km/hr, second 1/3 part with v_2 = 20 km/hr and rest 1/3 part with v_3 = 60 km/hr. What is the average speed the car-
(A) 18 km/hr (B) 45 km/hr (C) 6 km/hr (D) 22.5 km/hr
5. A car covers a distance of 2 km. in 2.5 min. if it covers half of the distance with speed 40 km/hr the rest distane it will cover with speed-
(A) 56 km/hr (B) 60 km/hr (C) 50 km/hr (D) 48 km/hr
6. A cyclist moving on a circular track of radius 40 m completes half a revolution in 40 sec. Its average velocity is-
(A) Zero (B) 5 m/sec. (C) 2 m/sec. (D) 3.5 m/sec.
7. A truck starts from rest with an acceleration of 1.5 m/sec² while a car 150 metre behind starts from rest with an acceleration of 2 m/sec². How long will it take before both the truck and car are side by side-
(A) 5.24 sec. (B) 24.5 sec. (C) 2.45 sec. (D) 52.4 sec.
8. A train of length 100 m is crossing a bridge 200 m in length at the speed of 72 km per hour. The time taken by the train to cross the bridge is-
(A) 24 sec (B) 15 sec (C) 10 min (D) 10 sec
9. Which of the following statements is wrong about a ball thrown vertically up-
(a) It is moving with constant acceleration
(b) It may have different velocities at the same position
(c) It may have two positions at the same time

(d) The angular momentum of the particle about origin remains conserved

(A) c only (B) c, d (C) b, c, d (D) a, b, c and d

10. A body travelling with uniform acceleration crosses two points A and B with velocities 20 m/sec and 30 m/sec respectively. Then the speed of the body at mid-point of A and B is-

(A) 25 m/sec (B) 25.5 m/sec (C) 24 m/sec (D) $10\sqrt{6}$ m/sec

11. A bus accelerates uniformly from rest and acquires a speed of 36 km/hour in 10 seconds. The acceleration is

(A) 1000 m/sec^2 (B) 1 m/sec^2 (C) 100 m/sec^2 (D) 10 m/sec^2

12. A body thrown up with a velocity reaches a maximum height of 50 meters. Another body with double the mass thrown up, with double the initial velocity will reach a maximum height of

(A) 100 metres (B) 200 metres (C) 10 metres (D) 400 metres

13. One car moving on a straight road covers one third of the distance with 20 km/hr and the rest with 60 km/hr. The average speed is

(A) 40 km/hr (B) 80 km/hr (C) $46\frac{2}{3}$ km/hr (D) 36 km/hr

14. A particle travels 10 m in first 5 sec and 10 m in next 3 sec. Assuming constant acceleration what is the distance travelled in next 2 sec.

(A) 8.3 m (B) 9.3 m (C) 10.3 m (D) none of these

15. Acceleration of a particle changes when

(A) direcion of velocity changes (B) magnitude of velocity changes

(C) both of above (D) speed changes

16. If a body of mass 3 kg is dropped from the top of a tower of height 50 m, then its K.E. after 3 sec will be

(A) 1296J (B) 1048J (C) 735J (D) zero

17. A body released from a great height falls freely towards earth. Another body is released from the same height exactly one second later. The separation between the two bodies two second after the release of the second body is

(A) 9.8 m (B) 49 m (C) 24.5 m (D) 19.6 m

SECTION-B

- **Multiple choice question with one or more than one correct answers**

1. Which of the following statements regarding the freely falling body is/are correct?

(A) The body is uniformly accelerated

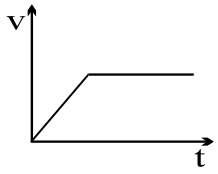
(B) The body is non-uniformly accelerated

(C) The distance travelled by the body in the first second, second second and third second are in the ratio of 1 : 3 : 5

(D) The distance travelled by the body in the first second, first two seconds and first three seconds are in the ratio of 1 : 4 : 9

2. The velocity time graph of an object is shown in figure.

Which of the following statement is/are correct ?



(A) The slanted portion of the v-t graph represents constant acceleration.

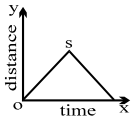
(B) The horizontal portion represents constant velocity

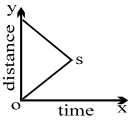
(C) Area under v-t graph gives the momentum change.

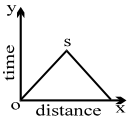
(D) Area under v-t graph is equal to acceleration

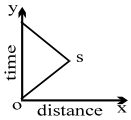
3. In an examination, the students were asked to draw distance -time graph of a school boy going from home straight to school and starting back home immediately (without any time loss). The following graphs

were drawn by four students. Which of these graphs do not depict the real situation ?

(A) 

(B) 

(C) 

(D) 

SECTION-C

- **Comprehension**

A "sun yacht" is a spacecraft with a large sail that is pushed by sunlight. Although such a push is tiny in every day circumstances, it can be large enough to send the space craft outward from the Sun on a cost-free but slow trip. Suppose that the spacecraft has a mass of 900 kg and received a push of 20 N.

1. The magnitude of the resulting acceleration is :

(A) 45 ms^2 (B) 18000 ms^2 (C) $\frac{1}{45}$ ms^2 (D) None of these

2. If the craft starts from rest how far will it travel in 1 min

(A) 40 m (B) 30 m (C) 100 m (D) None of these

3. How fast will it then be moving

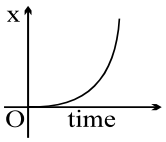
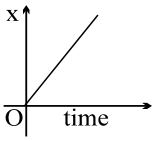
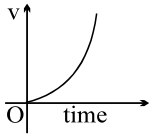
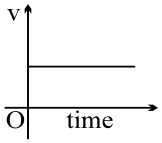
(A) 3/4 m/s (B) 4/3 m/s (C) 5/4 m/s (D) None of these

SECTION-D

- **Match the following (one to many)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. One or more than one entries of column-I may have the matching with the some entries of column-II and one entry of column-II may have one or more than one matching with entries of column-I

1.

Column I ***Displacement time(x - t)/velocity-time graph (v - t)***	**Column II** ***Type of motion***
(A) 	(P) Uniform motion
(B) 	(Q) Non-uniform motion
(C) 	(R) constant velocity
(D) 	(S) uniformly accelerated motion

ANSWER KEY

Exercise-III

Section-A

1. 2r, 2p

Section-B

1.	(B)	2.	(D)	3.	(D)	4.	(A)	5.	(C)
6.	(D)	7.	(C)	8.	(A)	9.	(D)	10.	(C)
11.	(C)	12.	(D)						

Section-C

1.	(B)	2.	(A)	3.	(A)	4.	(A)	5.	(B)
6.	(A)								

Section-D

1. (A)-(R), (B)-(S), (C)-(P), (D)-(Q)
2. (A)-(Q), (B)-(S), (C)-(P), (D)-(R)

Exercise-IV

Section-A

1.	(D)	2.	(A)	3.	(A)	4.	(A)	5.	(B)
6.	(C)	7.	(B)	8.	(B)	9.	(A)	10.	(B)
11.	(B)	12.	(B)	13.	(D)	14.	(A)	16.	(C)
16.	(A)	17.	(C)						

Section-B

1.	(A,C,D)	2.	(A,B)	3.	(B,C)

Section-C

1.	(C)	2.	(A)	3.	(B)

Section-D

1. (A)-(Q,S), (B)-(P,R), (C)-(Q), (D)-(P,R)

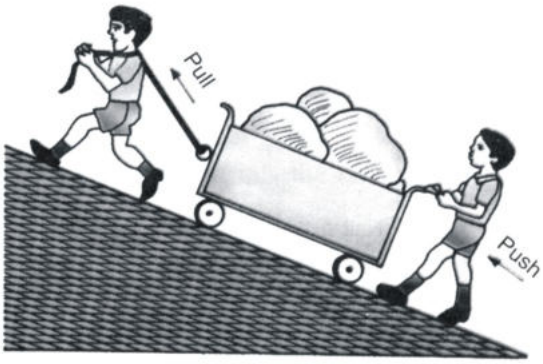
FORCE AND LAWS OF MOTION

CONTENTS IN THE CHAPTER

- INTRODUCTION
- FORCE
- NEWTON'S LAW OF MOTION
  - I. NEWTON'S FIRST LAW OF MOTION
  - II. NEWTON'S SECOND LAW OF MOTION
  - III. NEWTON'S THIRD LAW OF MOTION
- LAW OF CONSERVATION OF MOMENTUM
- FRICTION

FORCE AND LAWS OF MOTION

INTRODUCTION



From our day to day experience, we all are familiar with the concept of 'Force'. While opening a door, lifting a bucket or a bag, kicking a football or throwing a stone, we have to act differently and in many ways. We are either pushing or pulling the object. No non-living object moves on its own. We have to apply the effort in the form of push or pull. This pull or push is called force. Thus a force is an external agency that displaces or tends to displace a body from its position of rest.

The direction in which the object is pushed or pulled is called the direction of the force. Force has both magnitude and direction. It is a vector quantity.

FORCE

Force is the 'push' or 'pull' which can make a body move, stop a moving body, change the direction and speed of a moving body. Force cannot be seen but the effect of force on an object can be seen or felt.

◈ **Definition of Force**

A force is physical quantity which causes or tends to cause a motion in an object at rest or changes or tends to change the direction of motion of a moving object or changes or tends to change the size and shape of an object or change or tends to change the speed of an object.

◈ **Effect of force**

A force produces the following effects :-

- It can move or tend to move an object.
- It can stop or tend to stop an object in motion.
- It can change or tend to change the direction of motion of an object.
- It can increase or decrease the speed of an object.
- It can change the shape or size of an object.

TYPES OF FORCES

Broadly speaking forces are classified as being of two types. (i) Contact force, (ii) Non-contact force

1. **Contact force** : The force which act on a body either directly or through some connector are called contact forces.

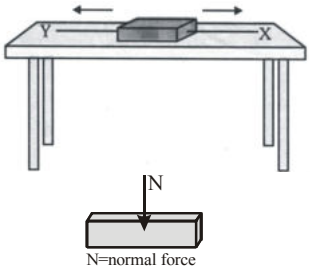
   Examples : Biological force, muscular force, mechanical force and frictional force are the examples of contact force.

   (a) Muscular Force : This force produced by the muscles of living beings is called muscular force or biological force.

   (b) Mechanical Force : The force generated by machines are called mechanical force.

   (c) Friction Force: A force which acts at the surface of contact, when one body moves or tends to move upon another body is called the force of friction.

(d) Resultant force : If a single force acting on a body produces the same acceleration as produced by a number of forces, that single force is called the resultant of these individual forces.



(e) Normal Force :-

The force acting perpendicular to the ground surface then the force is called normal force.

The force of friction has the following properties :

(i) It is produced only when one body is made to move upon another body.

(ii) It always opposes the motion of the body and tries to stop the body.

(iii) It wears off the surface of contact of two bodies.

It is the force of friction which makes it difficult for us to move heavy objects such as large boxes; carts laden with different kinds of substances, etc. Again, it is the force of friction which wears off the tyres of our bicycles, cars, trucks, etc.

2. Non-contact Force or Field force :

The force which do not make a direct contact with a body and act through space, without any connector are called non-contact force.

Examples:

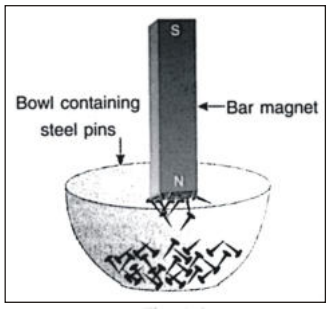
(i) The force of gravity of the earth is a non-contact force which attracts all bodies towards the earth.

(ii) The electrostatics force can pull tiny bits of dry paper is a non-contact force.

(iii) A magnet can attract common pins of steel from a distance and hence the magnetic force is non-contact force.

(a) Gravitational Force :-

$F = \frac{Gm_1m_2}{r^2}$, Here G is a universal gravitational constant & m_1 m_2 are masses, and r is a distance between two bodies.



(b) Electrostatics Force :-

$F = \frac{Kq_1q_2}{r^2}$, Here K is a Coulomb's constant & q_1 q_2 are charges, and r is a distance between two charges.

(c) Magnetic Force: The strange property of some substances to attract iron or steel objects towards itself is called magnetic property. The substance which has the above property is called a magnet.

As the objects of iron or steel move towards magnet, therefore we can say that they are acted upon by the force of magnet.

3. Balanced and unbalanced forces :

If a set of forces acting on a body produces no acceleration in it, the forces are said to be balanced. If it produces a non-zero acceleration, the forces are said to be unbalanced.

Definition of balance force :-

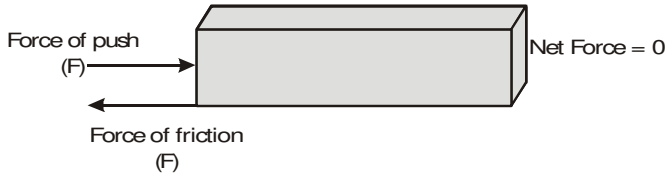
When two forces of equal magnitude but acting in opposite directions on an object simultaneously then the object continues in its state of rest of uniform motion in a straight line. Such forces acting on the object are known as balance force.

Examples of balanced force :-

1. When we push a wall, the wall does not move at all i.e., it remains at rest.

In this case, the force of push on the wall acts in the forward direction. On the other hand, the wall also exerts equal force on our hand in the backward direction. These two equal and opposite forces cancel out the effect of each other and hence these two forces are the balanced forces.

2. When we try to push a heavy box on a rough surface, it does not move.



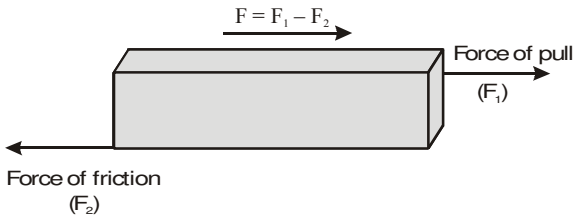
Definition of Unbalance force :-

When two forces of unequal magnitudes act in opposite directions on an object simultaneously then the object move in the direction of a large force. These forces acting on the object are known as unbalanced forces.

Examples of unbalanced force :-

1. When a boy drags a box on the floor, then an unbalanced force is acting on the box.

2. A bicycle will slow down if the rider stop pedaling it.

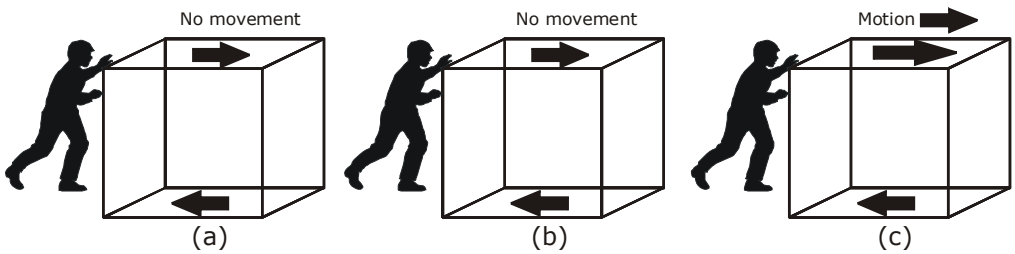


Newton's Thought

What happens when some children try to push a box on a rough floor?

Explanation

If they push the box with a small force, the box does not move because of friction acting in a direction opposite to the push (see figure a). This frictional force arises between two surfaces in contact. Here, the friction is between the bottom of the box and floor's rough surface. It balances the pushing force and therefore the box does not move. If the children push the box harder (see figure b), the box still does not move. This is because the frictional force still balances the pushing force. If the children continue to increase the push force on the box, at some point the pushing force becomes bigger than the frictional force (see figure c). That is, there is an unbalanced force due to which the box starts moving (accelerating).



NEWTON'S LAWS OF MOTION

I. NEWTON'S FIRST LAW OF MOTION :

A body at rest will remain at rest and a body in motion will remain in uniform motion unless an unbalanced forces acts on it to change its state of rest or of uniform motion.

The above law can be understood in two parts.

(i) A body at rest remains at rest unless an external unbalanced force acts on it to change its state of rest.

Ex. Consider a wooden block kept on a horizontal surface at rest. It will remain at rest unless somebody moves it.

(ii) A body in motion will remain in uniform motion unless an external unbalanced force acts on it to change its state of uniform motion.

Sir Isaac Newton

INERTIA :

(i) There is an inherent property of an object by virtue of which it cannot change its state of motion or rest by itself. This property is called 'inertia'.

(ii) Inertia is of two types– inertia of rest and inertia of motion.

(A) Inertia of rest:

If the body is at rest, it will continue to be at rest unless some external force is applied on it. Examples are following.

(i) When a train at rest starts moving suddenly, a passenger standing inside the compartment tends to fall backward.

(ii) When a carpet is beaten up with a stick, the dust particles are detached.

(iii) When a bullet is fired into a glass pane, it pierces a hole only at the point where the bullet hits the glass without breaking the entire glass pane into pieces.

(B) Inertia of motion :

When a body is in uniform motion, it will continue to remain in its uniform motion, i.e. it resists any change in its state of motion due to inertia of motion.

(i) when a person jumps out of a moving bus, he should run in the direction in which bus is moving otherwise he will fall down.

(ii) A train moving with a uniform speed and if a ball is thrown upwards inside the train by a passenger, then the ball comes back to his hand.

Mass and Inertia :

(i) Larger the mass of the body, larger is the inertia.

(ii) eg. it is more difficult to stop a cricket ball than a tennis ball.

◈ Inertial Mass :

(i) If equal forces are applied for equal intervals of time, then the change in the velocity of the lighter body is larger than the change in velocity of the heavier body.

(ii) Thus $F\Delta t \propto \Delta v$ or $F\Delta t = m \Delta v$

where mv is proportionality constant that depends on the body.

(iii) $m = F/a$

$m \rightarrow$ "inertial mass" of the body and is inversely proportional to the acceleration.

(iv) $\frac{a_1}{a_2} = \frac{m_2}{m_1}$

◈ **Gravitational Mass :**

(i) Gravitational mass of a body is the inherent property measured by a physical balance or beam balance.

(ii) When the balance beam becomes horizontal then the masses on both the pans are equal because the force of gravity experienced by both the masses is equal.

(iii) Gravitational mass of a body does not depend on the place where it is measured, i.e. it will be the same on the earth as well as on the moon.

(iv) Inertial mass is related to the motion of the body while the gravitational mass is related to the force of attraction in equilibrium.

(v) Both of them are proportional to the quantity of matter contained in the body.

(vi) Both of them have additive property.

(vii) None of them is affected by chemical changes.

(viii) Both of them have same units, i.e. kilogram.

◈ **Linear Momentum**

Definition :

The product of mass and velocity of a body is called **Linear momentum,** it is denoted by P.

Linear momentum = mass × velocity

$$\boxed{\vec{P} = m\vec{v}}$$

◈ **Conclusion :-**

(a) The momentum of the moving body is proportional to

(i) mass of the body and (ii) velocity of the body.

(b) Momentum is a **vector quantity**.

(c) Magnitude of momentum, P = mass × speed

P = mv

(d) Direction of momentum of a body is same as that of the direction of the velocity of the body.

◈ **UNITS OF MOMENTUM**

Momentum = mass × velocity

∴ Unit of momentum = unit of mass × unit of velocity

(i) S.I. unit of momentum is **kg ms^{-1}.**

(ii) In **CGS system**, unit of momentum is **g cm^{-1}.**

(iii) The other unit of momentum is N-s.

Note:

(i) Linear momentum has a sense of direction. Therefore it is a vector quantity.

(ii) The direction of linear momentum of a body at any instant is same as that of the velocity of the body at that instant.

(iii) A body moving in a curved path, the direction of velocity at a point is a tangent drawn at that point. Therefore, the direction of linear momentum is also tangential.

Newton's Thought

(i) A car and a truck both are moving with same velocities. Which one has more momentum?
(ii) A car and a truck have same momentum. Which one has more velocity?

Explanation

(i) For a given velocity, the momentum is directly proportional to the mass of the object ($p \propto m$). This means more the mass, more will be the momentum and vice-versa. Here, velocity of both truck and car is same. Since, the mass of a truck is greater than the mass of a car, therefore, the momentum of truck is more than the momentum of car.

(ii) For a given momentum, the velocity is inversely proportional to the mass of the object $\left(V \propto \frac{1}{m}\right)$ This means smaller the mass, more will be the velocity of an object and vice versa. Here, momentum of both truck and car is same. Since, the mass of a car is smaller than the mass of a truck, therefore, the velocity of car is more than the velocity of truck.

II. NEWTON'S SECOND LAW OF MOTION:

According to this law, the change in momentum of a body per unit time (i.e. rate of change of momentum) is directly proportional to the unbalanced force acting on the body and the change in momentum takes place in the direction of the unbalanced force on the body.

i.e. $\vec{F} \propto \frac{dp}{dt}$

where, dp = change in momentum and dt = time taken for this change in momentum.

◈ **Derivation of second law of motion :-**

Consider a body of mass m moving with initial velocity u. Let a force F acts on the body for time t .

Initial momentum of the body, $P_i = mu$

Final momentum of the body, $P_f = mv$

Now, change in momentum of the body = $P_f - P_i = mv - mu = m(v - u)$

Time taken to change this momentum = $(t - 0) = t$

$\therefore$ Rate of change of momentum = $\frac{Change \text{ of momentum}}{Time \text{ taken}} = \frac{m(v-u)}{t}$

According to the definition of Newton's second law of motion

Force applied $\propto$ rate of change of momentum

or $F \propto \frac{m(v-u)}{t}$ ... (i)

Since $v = u + at$

or $\left(\frac{(v-u)}{t}\right) = a$

Therefore, equation (i) can be written as

$\therefore$ $F \propto ma$

or $F = k\,ma$ ... (ii)

where k is constant of proportionality

If $F = 1$ unit

$m = 1$ unit

and $a = 1$ unit

Then from equation (ii) $1 = k$ or $k = 1$

Put this value of k = 1 in equation (ii), we get

$$\boxed{F = ma}$$

Thus, force acting on the body is directly proportional to (i) its mass (m) and (ii) its acceleration (a). Equation (i) gives the mathematical form of Newton's second law of motion.

Newton's Thought

Equal forces are applied to a car and a truck which produce acceleration in both of them. Which one has smaller acceleration.

Explanation

For a given force, the acceleration produced in the body is inversely proportional to the mass of the object ($a \propto 1/m$). This means more the mass of an object, less will be the acceleration produced in it. Here, force applied on the truck as well as the car is same. Since, the mass of a truck is greater than the mass of a car, therefore, the acceleration of truck is smaller than the acceleration of car.

◈ **UNITS OF FORCE :-**

We know, $F = ma$

If $m = 1$ unit and $a = 1$ unit

Then $F = 1$ unit

SI unit of force :-

We know, $F = ma$

SI unit of mass, $m = 1$ kg

SI unit of acceleration, $a = 1\ ms^{-2}$

$\therefore$ SI unit of force = $1 \text{ kg} \times 1\ ms^{-2} = 1 \text{ kg } ms^{-2}$.

$1 \text{ kg } ms^{-2}$ is known as 1 newton (N).

$\therefore$ **1 newton (N) = 1 kg ms^{-2}**

(i) Definition of Newton (N) :-

The force is said to be 1 newton if it products $1\ ms^{-2}$ acceleration in a body of 1 kg mass.

C.G.S. unit of force :-

We know, $F = ma$

In CGS system, unit of mass, $m = 1$ g

unit of acceleration, $a = 1\ cm\ s^{-2}$

$\therefore$ unit of force = $1 \text{ g} \times 1 \text{ cm } s^{-2} = 1 \text{ g cm } s^{-2}$

$1 \text{ g cm } s^{-2}$ is known as 1 dyne

$1 \text{ dyne} = 1 \text{ g cm } s^{-2}$

(ii) Definition of Dyne :-

The force is said to be 1 dyne if it produces $1 \text{ cm } s^{-2}$ acceleration in a body of 1 g mass.

RELATION BETWEEN NEWTON AND DYNE

We know, $1 \text{ newton (N)} = 1 \text{ kg } ms^{-2}$ ... (i)

Now $1 \text{ kg} = 1000 \text{ g} = 10^3 \text{ g}$

$1 \text{ m} = 100 \text{ cm} = 10^2 \text{ cm}$

Put these values in equation (i), we get

$\therefore$ $1 \text{ newton} = 10^3 \text{ g} \times 10^2 \text{ cm } s^{-2} = 10^5 \text{ g cm } s^{-2}$

But $1 \text{ g cm } s^{-2} = 1 \text{ dyne}$

$\therefore$ **1 newton = 10^5 dyne**

◈ NEWTON'S SECOND LAW IN TERMS OF LINEAR MOMENTUM

Definition : The rate of change of momentum of a body with respect to time is directly proportional to the external force acting on the body and takes place in the direction of force.

Suppose a body of mass m is acted upon by an unbalanced external force F which creates an acceleration a in the body. Let the initial velocity of the body be u. Let the force continues to act for a time interval t and the final velocity of the body be v. Then we can write

$$F = ma = m\left(\frac{v-u}{t}\right) \quad \Rightarrow \quad \boxed{F = \frac{mv-mu}{t}}$$

Here, mv = Final momentum of the body (P_f)

mu = Initial momentum of the body (P_i)

Then mv – mu = (P_f – P_i) represents the change in momentum.

The change in momentum written as Δp and is called delta P.

$$\boxed{F = \frac{\Delta p}{t}}$$

◈ IMPULSE :

(i) If a force F is applied on a body of mass m for a time interval Δt and if the change in velocity is Δv then

$m \Delta v = F \Delta t$

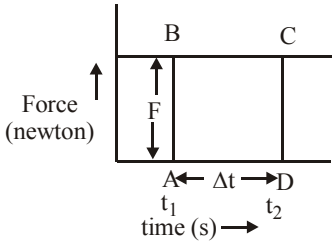
(ii) $\therefore$ Impulse = $F\,dt = m \Delta v$

Impulse = change in momentum

(iii) Unit of impulse is newton × second, i.e. NS

From the force time graph :

(i) area of rectangle = $F\Delta t$ = impulse



Examples of Impulse

(i) A bullet fired from a gun with a large velocity resulting in a large momentum when strikes a body, its velocity becomes zero in a short interval of time.

(ii) The rate of change of momentum is very large and it exerts a large force and so that it can easily pierce the body.

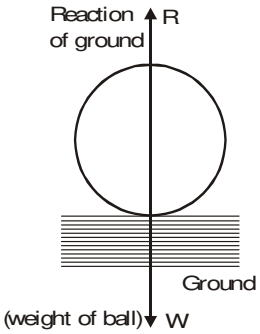
(iii) While catching a cricket ball a player moves his hands backwards. Cricket ball coming towards fielder has a large momentum. By doing so he increases the time interval to reduce the momentum of the ball. Rate of change of momentum becomes slow.

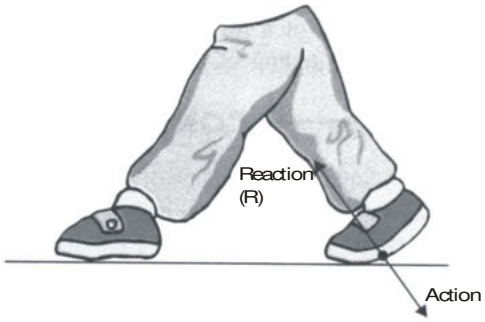
(iv) The ball exerts lesser force.

(v) He does not get hurt.

III. NEWTON'S THIRD LAW OF MOTION:

Definition : For each and every action, there is equal and opposite reaction.





If a body A exerts force $\vec{F}$ on another body B, then B exerts a force $-\vec{F}$ on A, the two forces acting along the same line. The two forces $\vec{F}$ and $-\vec{F}$ connected by Newton's third law are called action-reaction pair. Any one may be called 'action' and the other 'reaction'.

Action and reaction acts on different bodies hence they never cancel each other.

Note : Action and reactions forces occur simultaneously. It is wrong to think that first action occurs and it is followed by reaction.

An important conclusion :- When action-reaction forces are acting on two bodies of masses m_A and m_B then

From eqn. $F_{AB} = -F_{BA}$

$m_A a_A = -m_B a_B$

$$\frac{a_A}{a_B} = \frac{m_B}{m_A}$$

$$a \propto \frac{1}{m}$$

DO YOU KNOW ?

MISCONCEPTION : The action and reaction forces acting on a body are equal and opposite and therefore cancel out the effect of each other.

CONCEPT : Action and reaction do not cancel out the effect of each other because they act on different bodies.

MISCONCEPTION : Any pair of equal and opposite forces is a action-reaction pair.

CONCEPT : Only those forces from an action-reaction pair which involve the two bodies responsible for action-reaction.

Some other examples of Newton's third law :

1. When a bullet is fired from a gun, we observe recoiling of the gun. The gun acts on bullet i.e., exerts a force on the bullet; simultaneously, the bullet reacts on the gun.

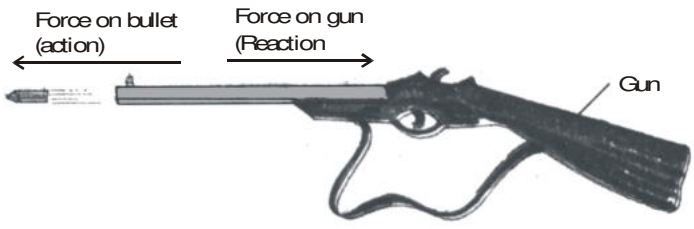


Fig. A bullet fired from a gun

2. While walking or running, you push the ground in the backward direction with your feet. The ground simultaneously exerts a force of equal magnified in the forward direction on feet. This force enables us to walk.

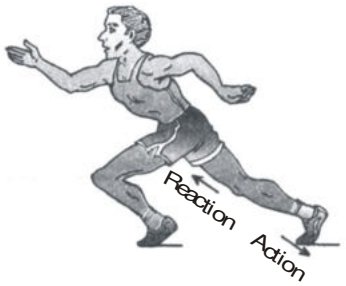
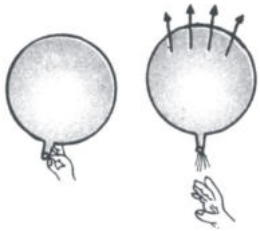


Fig. A running athlete

3. When a man jumps from a boat, the boat also experiences a backward jerk. This is due to the action-reaction pair as shown in figure.

Fig. A jumping from a boat

4. Inflate a balloon and leave it. You will observe that the balloon moves in opposite direction to the opening in balloon through which the air is coming out.



5. A ball rebounds after striking against a floor.

When a ball strikes against a floor, it exerts a force on the floor. According to Newton's third law of motion, the floor exerts an equal and opposite force on the ball. Due to this reaction, the ball rebounds.

6. How do we swim ?

While swimming, a swimmer pushes the water backward with his hands. The reaction offered by the water to the swimmer pushes him forward.

7. A boatman pushes the river bank with a bamboo pole to take his boat into the river.

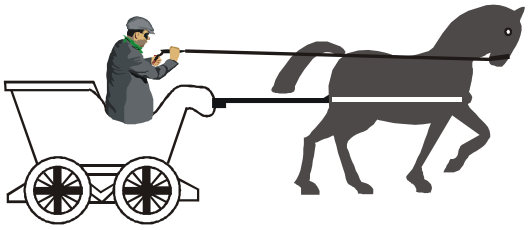
When the boatman pushes the river bank with a bamboo pole, the river bank offers an equal and opposite reaction. This reaction helps the boat to move into the river.

8. Why a fireman struggles to hold a hose-pipe ?

A fireman has to make a great effort to hold a hose-pipe to throw a stream of water on fire to extinguish it. This is because the stream of water rushing through the hose-pipe in the forward direction with a large speed exerts a large force on the hose-pipe in the backward direction.

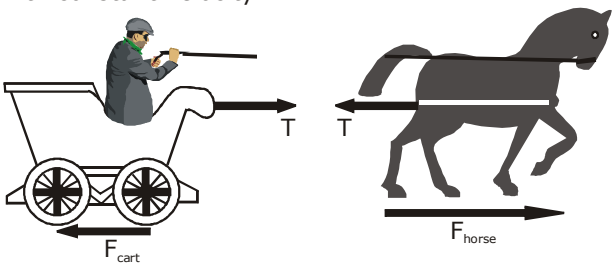
Newton's Thought

A horse pulls a cart along a level road, causing the cart to accelerate, as shown in figure 25. Newton's third law states that the cart exerts an equal and opposite force on the horse. In view of this, how can the cart accelerate? Under what condition does the horse-cart system move with constant velocity?



Explanation

According to Newton's third law, action-reaction forces act on different objects - the horse exerts a force (T) on the cart, and the cart exerts an equal magnitude and oppositely directed force (T) on the horse. But, horse also exerts a force (due to friction) on the road in backward direction, as a result of which the road exerts a force 'F_{horse}' on the horse in forward direction. Thus, the horse starts moving in forward direction. Now, cart is attached to the horse, thus, the wheels of cart start rotating which exerts a force 'F_{cart}' (due to friction) on the road in backward direction, as a result of which the road also exerts an equal force on the cart in forward direction. This is how, the horse-cart system moves. When 'F_{horse}' is greater than 'F_{cart}' the horse-cart system accelerates. When 'F_{horse}' is equal to 'F_{cart}', the horse-cart system moves with constant velocity.

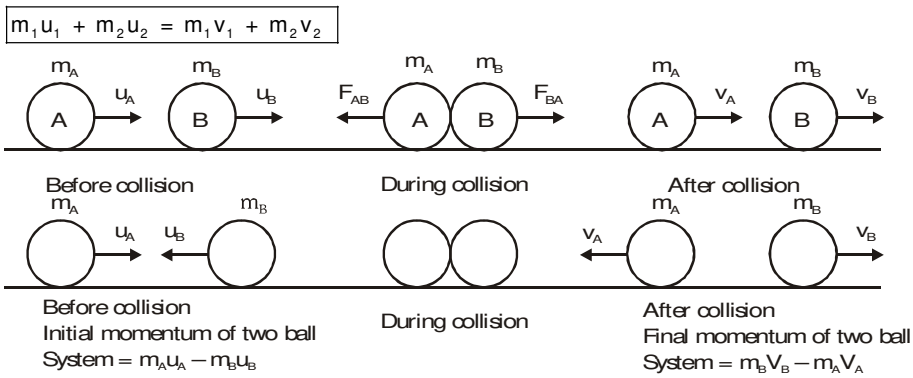


LAW OF CONSERVATION OF LINEAR MOMENTUM

We know that if a moving body strikes a body at rest, the moving body slows down and the stationary body starts moving. Whereas the first body loses momentum, the second body gains momentum. We shall observe that the total momentum before impact is equal to total momentum after impact.

If two bodies of masses m_1, m_2 are initially moving with velocities u_1, u_2 and after collision they start moving with velocities v_I and v_2 respectively, then

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

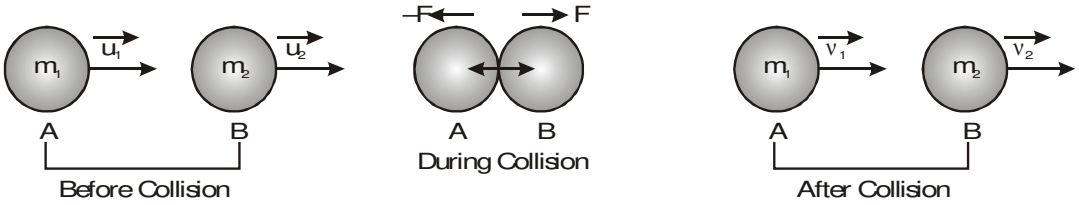


i.e., total momentum before collision is equal to total momentum after impact.

If one body gains momentum, the other loses an equal amount of momentum.

Proof of the law of conservation of linear momentum:

Consider a system consisting of two bodies A and B of (say glass spheres) masses m_1 and m_2 respectively. Let these bodies are moving with velocities u_1 and u_2 as shown in figure. Let $u_1 > u_2$. Let these bodies collide with each other for a small interval of time 'dt'. At the time of collision, body A exerts a force F on body B and body B exerts equal and opposite force (– F) on body A. Due to these forces, the momentum of the bodies changes. Let v_1 and v_2 be the velocities of body A and body B respectively after the collision.



Initial momentum of body A = $m_1 u_1$

Initial momentum of body B = $m_2 u_2$

Final momentum of body A = $m_1 v_1$

Final momentum of body B = $m_2 v_2$

Total momentum of the system before collision = $m_1u_1 + m_2u_2$

Total momentum of the system after collision = $m_1v_1 + m_2v_2$

Now, the rate of change of momentum of body A

$$= \frac{\text{Change in momentum of body A}}{\text{time taken}}$$

$$= \frac{\text{Final momentum} - \text{Initial momentum}}{\text{time taken}}$$

$$= \frac{(m_1v_1 - m_2v_2)}{dt}$$

According to Newton's second law of motion,

Force acting on body A = rate of change of momentum of body A

i.e. $$F = \frac{(m_1v_1 - m_1u_1)}{dt} \quad \ldots (1)$$

Now, rate of change of momentum of body B

$$= \frac{Change \text{ in momentum of body B}}{time \text{ taken}} = \frac{(m_2v_2 - m_2u_2)}{dt}$$

According to Newton's second law of motion force acting on body B = rate of change of momentum of body B

i.e. $$-F = \frac{(m_2v_2 - m_2u_2)}{dt}$$

or $$F = \frac{-(m_2v_2 - m_2u_2)}{dt} = \frac{(m_2u_2 - m_2v_2)}{dt} \quad \ldots (2)$$

Equating eqns. (1) and (2), we get

$$\boxed{\frac{(m_2u_2 - m_2v_2)}{dt} = \frac{(m_1v_1 - m_1u_1)}{dt}}$$

or $m_1u_1 + m_2u_2 = m_1V_1 + m_2V_2$

i.e. Total momentum of the system (i.e. bodies A and B) before collision = Total momentum of the system (i.e. bodies A and B) after collision.

This is the law of conservation of linear momentum.

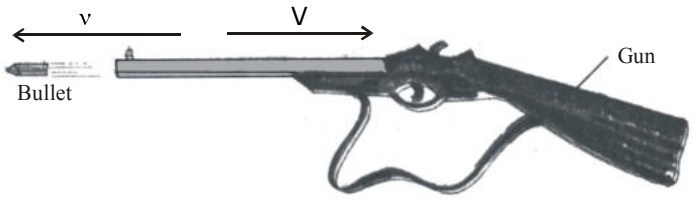
Examples to illustrate the law of conservation of momentum

1. Recoil of a gun. The recoil of a gun can be explained with the help of the law of conservation of momentum.

The bullet inside the gun and the gun itself form a system. Thus, the system is gun + bullet. Before firing, the gun and the bullet are at rest, therefore, momentum of the system before firing is zero.

When the bullet is fired, it leaves the gun in the forward direction with certain momentum. Since no external force acts on the system, so the momentum of the system (gun + bullet) must be zero after firing. This is possible only if the gun moves backward with a momentum equal to the momentum of the bullet. That is, why gun recoils or moves backward figure.

Recoil Velocity. The velocity with which the gun moves backward after firing a bullet is known as recoil velocity.



A bullet fired from a gun

Calculation of Recoil Velocity of a Gun

Let mass of the bullet = m

Velocity of the bullet after firing = $\vec{v}$

Mass of the gun = M

Velocity of the gun after firing = $\vec{V}$

Since the system is at rest before firing, so momentum of the system (gun + bullet) before firing = 0

Total momentum of the system (gun + bullet) after firing

= momentum of gun + momentum of bullet = $M\vec{V} + m\vec{v}$

According to the law of conservation of momentum

Momentum of the system after firing = Momentum of the system before firing

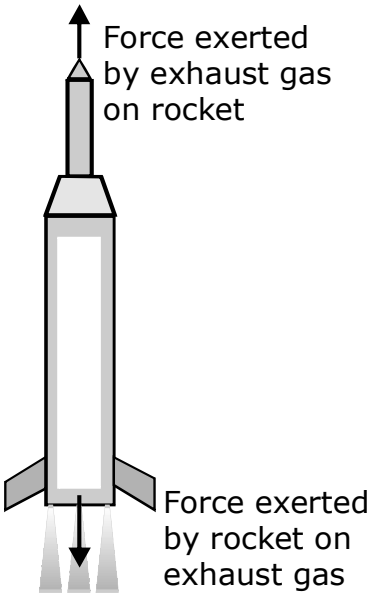
i.e. $M\vec{V} + m\vec{v} = 0$ $\quad M\vec{V} = -m\vec{v}$ or $\quad \vec{V} = -\left(\frac{m}{M}\right)\vec{v}$

Negative sign shows that the direction of the velocity of the gun after firing is opposite to the direction of the velocity of the bullet.

2. Rocket propulsion (Movement of a rocket in the upward direction)

The movement of a rocket in the upward direction can also be explained with the help of the law of conservation of momentum.

The momentum of a rocket before it is fired is zero. When the rocket is fired, gases are produced in the combustion chamber of the rocket due to the burning of fuel. These gases come out of the rear of the rocket with high speed. The direction of the momentum of the gases coming out of the rocket is in the downward direction. To conserve the momentum of the system (rocket + gases), the rocket moves upward with a momentum equal to the momentum of the gases. The rocket continues to move upward as long as the gases are ejected out of the rocket.



Action-reaction pairs in rocket propulsion

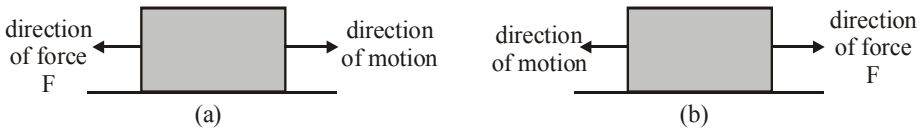
3. Inflated balloon lying on the surface of a floor moves forward when pierced with a pin.

The momentum of the inflated balloon before it is pierced with a pin is zero. When it is pierced with a pin. air in it comes out with a speed in the backward direction. To conserve the momentum, the balloon moves in the forward direction.

FRICTION

If the switch off the engine of car it will stop after moving a certain distance. It means that some retarding force is acting on the car which stops it. The force opposing the motion of the car is called "force of friction".

(i) The frictional force is tangential to the surface in contact and always in a direction opposite to the direction of motion of the object.



(ii) Frictional force is a force opposing the relative motion between two surfaces which are in contact with each other.

(iii) The force of friction arises due to the interlocking of irregular projections on the two surfaces and is called as "force of contact".

TYPES OF FRICTION

(A) Static friction :

The frictional force that exists between the body and the surface so long as they are relatively at rest even when the external force acts, is called the static friction.

(B) Limiting friction :

(i) When there is no external force acting on the body, the frictional force is zero.

(ii) If we increase the magnitude of the external force, the static friction also increases.

(iii) At one pt, when there is a slight increase in the magnitude of the external force, the body just starts sliding over the surface.

(iv) The force of friction at the limiting stage is called the 'limiting friction.'

(v) The limiting friction depends upon the nature of the two surfaces in contact.

(C) Kinetic or Sliding friction :

(i) When the external force exceeds the limiting friction, the body just starts sliding.

(ii) The minimum force required to maintain the motion of the body over the other surface is called the "kinetic friction".

(iii) The frictional force that exists between the two surfaces when there is a uniform relative motion between them is called the "dynamic friction" or "sliding friction".

(iv) Kinetic friction is smaller than the limiting friction.

(D) Rolling friction :

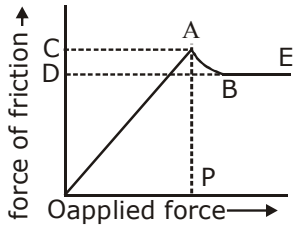
(i) The frictional force that exists between the two surfaces when a body rolls over the other is called the "rolling friction".

(ii) It deforms the surface over which it rolls.

(iii) Rolling body it-self gets deformed at the pt of contact over the surface.

◈ **Variation of frictional force with applied forces :**

(i) The part OA of the graph shows that the static friction increases with the increase in applied force.



(ii) The force of friction is maximum at a pt A which is equal to AP.

(iii) If the applied force is increased further, the body will continue to be in motion but the force of friction is slightly lesser.

(iv) After this the force of friction remains constant.

Note : Rolling friction is smaller than sliding friction which in turn is smaller than the limiting friction.

◈ **Factors affecting friction**

The force of friction depends upon the following factors :

(i) Materials of the bodies in contact.

(ii) Roughness of the surfaces in contact

(iii) Force of friction is independent of the area of the two surfaces in contact.

(iv) The limiting frictional force is directly proportional to the normal reaction.

◈ **COEFFICIENT OF FRICTION**

(i) Coefficient of static friction (μ_s)

$$\mu_s = \frac{\text{limiting frictional force}}{\text{normal reaction}} = \frac{f_s}{R}$$

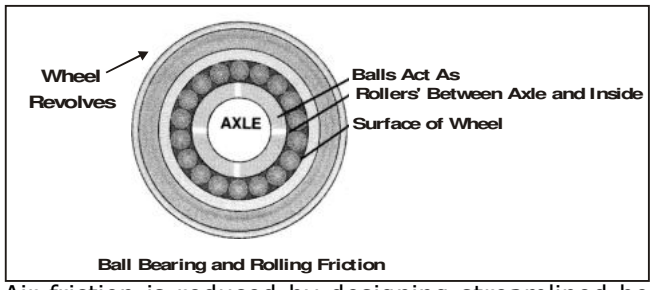
(ii) Coefficient of kinetic friction (μ_k)

$$\mu_k = \frac{\text{force of kinetic friction}}{\text{normal reaction}} = \frac{f_k}{R}$$

REDUCING FRICTION

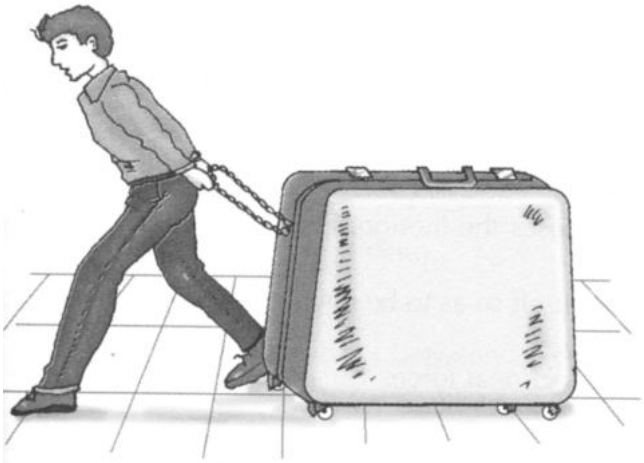
Frictional force can be reduced in the following ways :

1. **Use of lubricants :** In machines, friction can be reduced by applying lubricants between the contact surfaces to fill the fine pores or depressions in the surfaces and make them smooth thereby reducing friction.
2. **Polishing :** unevenness of the surfaces can be reduced by polishing, thereby reducing the friction.
3. **Use of ball bearings :** In rotating machines, shafts are mounted on ball bearings. By doing so, rolling friction occurs lesser than sliding friction, thereby reducing the friction.



Ball Bearing and Rolling Friction

4. **By streamlining :** Air friction is reduced by designing streamlined bodies of cars or aeroplanes. Similarly, if the bodies of boats and ships are streamlined, friction of water can be reduced.
5. **Wheels:** If a suitcase is fitted with wheels,it is easier to move it because the friction between the wheels and the ground is less.


Wheels reduce friction

DISADVANTAGES OF FRICTION

1. **Wear and Tear :** In machine parts like gears, brakes when they come in contact with each other continuously, they wear out gradually, which should be replaced time to time.
2. Friction reduces efficiency of the machine.
3. Friction in machine produces heat and undesirable noise which damages the machine. To avoid excessive heating, water is circulated in machines generally.

APPLICATIONS OF FRICTIONAL FORCES

1. We would not be able to walk if there had been no friction b/w the soles of our shoes and the ground.
2. If there had been no friction, the wheels of a car will slip instead of rotating and stop moving. For that we have to increase the friction by making the tyres corrugated to get better grip of tyres on the road. Also, the friction is increased.
3. When brakes are applied, the vehicle stops due to the force of friction b/w the brake lining and the drum.
4. In the absence of friction, we cannot write on a blackboard with a chalk stick because the chalk stick will slide off the board without leaving any mark on the board.

SOLVED PROBLEMS

Ex.1 Which of the following has more inertia :
(a) a rubber ball and a stone of the same size ?
(b) a bicycle and a train ?
(c) a five rupees coin and one-rupee coin ?

Sol. Mass of a body is the measure of its inertia; i.e., more the mass more is the inertia. Keeping this in mind :
(a) Stone has more inertia.
(b) Train has more inertia.
(c) Five rupees coin has more inertia.

Ex.2 In the following example, try to identify the number of times the velocity of the ball changes. "A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team : Also identify the agent supplying the force in each case.

Sol. The velocity of the football changes four times
First time the velocity changes when the player applies force to kick the ball towards another player of his team.
Second time the velocity changes when the other player kicks the ball towards the goal.
Third time the velocity changes when the goalkeeper collects the ball by applying force in the direction opposite to the direction of the motion of the ball.
Fourth time the velocity changes when the goalkeeper kicks the ball towards the player of his own team by applying force.

Ex.3 Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.

Sol. When the branch is suddenly set in motion, the leaves attached to it tend to continue in their state of rest because of inertia of rest. It generates a lot of strain at the junction of leaves and the branch. Because of this strain some leaves get detached from the branch.

Ex.4 Why do you fall in the forward direction when a moving bus apply brakes to stop and fall backward when it accelerates from rest ?

Sol. The bus and the persons in it are in the state of motion before the application of the brakes. When the brakes are suddenly applied, the bus comes to the state of rest, the lower part of passengers which is in contact with bus comes to rest, but the upper part tends to continue in the state of motion because of inertia of motion. Therefore, they fall in forward direction. Conversely, when the bus is in the state of rest, the passengers in it have inertia of rest. When the bus accelerates suddenly, the passengers tend to continue in their state of rest and hence are left behind, relative to the position of bus. Therefore, they fall in the backward direction.

Ex.5 If action is always equal to the reaction, explain how a horse can pull a cart.

Sol. When a horse pulls a cart with a certain force, then the cart pulls the horse with the same force and the system of horse and cart should not move.
But, if we analyze the problem carefully, then horse not only applies force on the cart, but also pushes the earth backward with his feet. The earth reacts back in this action of the horse and pushes it in the forward direction. The force applied by the horse on the earth is insufficient to move the earth, but the force applied by the earth is sufficient to make the horse to move in the forward direction.
This unbalanced force applied by the earth makes the system of horse and cart to move in the forward direction.

Ex.6 Explain, why is it difficult for a fireman to hold a hose pipe, which ejects large amounts of water at high velocity.

Sol. We can explain the above observation on the basis of law of conservation of momentum. When a system of the hose and water is not ejecting any water its momentum is zero. When the water issues out from the hose with a high velocity, it has momentum in the forward direction. Therefore, in order to conserve momentum the hose tends to move in the backward direction and hence is difficult to hold.

Ex.7 From a rifle of mass 4 kg, a bullet of mass 50 g is fired with an initial velocity of 35 ms^{-1}. Calculate the initial recoil velocity of the rifle.

Sol. Initial mass of rifle = 4 kg

Let initial velocity of recoil of rifle = v

Initial momentum of the rifle = 4 x v

Initial mass of bullet = 50 g

$$= \frac{50}{1000}kg = 0.05kg$$

Initial velocity of bullet = 35 ms^{-1}

Initial momentum of bullet = 0.05 × 35

Using the law of conservation of momentum ;

Momentum of the rifle = Momentum of the bullet

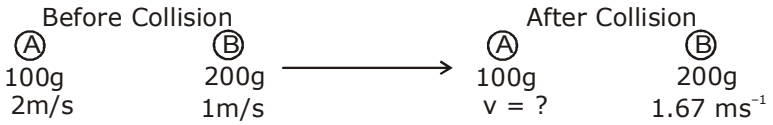
$4 \times v = 0.05 \times 35$

$v = \frac{0.05 \times 35}{4}$

$v = 0.4375\ ms^{-1}$

Ex.8 Two objects of masses 100 g and 200 g are moving along the same line and direction, with velocities 2 ms^{-1} and 1 ms^{-1}, respectively. They collide and after the collision, the second object moves with a velocity of 1.67 ms^{-1}. Determine the velocity of the first object.

Sol.



Let the 100 g and 200 g objects be A and B as shown in above figure.

Initial momentum of A = 100 × 2 = 200 g ms^{-1}

Initial momentum of B = 200 × 1 = 200 g ms^{-1}

∴ Total momentum of A and B before collision

= 200 + 200 = 400 g ms^{-1}

Let the velocity of A after collision = V

∴ Momentum of A after collision = 100 × V

Also, Momentum of B after collision

= 200 × 1.67 = 334 g ms^{-1}

∴ Total momentum of A and B after collision

= 100 × V + 334

Using the Law of conservation of momentum.

Momentum of A and B after collision = Momentum of A and B before collision

$100 \times V + 334 = 400$

$100 \times V = 400 - 334$

$\Rightarrow V = \frac{66}{100}$

$V = 0.66\ ms^{-1}$

Ex.9 An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity ? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.

Sol. No, the object will not be able to travel with non-zero velocity because there is net zero external unbalanced force. However, this will apply only on the surface of the earth where forces of gravity and friction always act on the object.
If the object is in deep space and is completely free from the forces of friction and gravitation, such that it is moving with non-zero velocity, then it will continue moving with the same velocity and in the same direction.

Ex.10 When a carpet is beaten with a stick, dust comes out of it. Explain.

Sol. Initially, the carpet and loose dust in it are in the state of rest. When the carpet is hit with a stick, it is suddenly set into motion, but the loose dust in it remains in the state of rest because of inertia of rest. Thus, in a way dust is left behind relative to carpet and hence comes out in air.

Ex.11 Why it is advised to tie any luggage kept on the roof of a bus with a rope?

Sol. Luggage on the top of the bus is a loose fixture and not a compact part of the bus. Thus, when a speeding bus brakes suddenly, the luggage continues moving forward because of inertia of motion and is likely to fall off the bus. Conversely, if a stationary bus accelerates suddenly, the luggage continues in the same state because of inertia of rest and hence is left behind relative to bus such that it falls backward. To avoid the falling of luggage, it is tied with a rope.

Ex.12 A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because,
(a) the batsman did not hit the ball hard enough.
(b) velocity is proportional to the force exerted on the ball.
(c) there is a force on the ball opposing the motion.
(d) there is no unbalanced force on the ball, so the ball would want to come to rest.

Sol. Correct Answer : (c)
There is force on the ball opposing the motion.
This force is the force of friction between the ball and the surface of ground.

Ex.13 A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes (Hint : 1 metric tonne = 1000 kg.)

Sol. Initial velocity of truck (u) = 0
Time (t) = 20 s
Distance covered (S) = 400 m
Acceleration (a) = ?
Mass of truck (m) 7 tonne = 7000 kg
Force on truck We know ; (F) = ?
We know ;

$S = ut + 1/2\ at^2$

$\Rightarrow \quad 400 = 0 \times 20 + 1/2 \times a \times (20)^2$

$\Rightarrow \quad 400 = 200a$

$\Rightarrow \quad a = \frac{400}{200} = 2ms^{-1}$

Force on truck (F) = ma
= 7000 x 2
= 14000 N

Ex.14 A stone of 1 kg is thrown with a velocity of 20 ms^{-1} across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice ?

Sol. Mass of stone (m) = 1 kg
Initial velocity of stone (u) = 20 ms^{-1}
Final velocity of stone (v) = 0
Distance covered by the stone (s) = 50 m
Acceleration of stone (a) = ?
Force acting on the stone due to friction (F) = ?
We know : $v^2 - u^2 = 2as$

$(0)^2 - (20)^2 = 2a \times 50$

$-400 = 100\ a$

$a = \frac{-400}{100} = -4$

$a = -4\ ms^{-2}$

$\therefore$ Force of friction (F) = ma

$= 1 \times (-4)$

$= -4N$

Negative sign signifies that force of friction is acting in the direction opposite to the direction of motion of the stone.

Ex.15 A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a frictional force of 5000 N, then calculate:
(a) the net accelerating force;
(b) the acceleration of the train, and
(c) the force of wagon 1 on wagon 2.

Sol. (a) Force exerted by the engine = 40,000 N
Force of friction exerted by the tracks = 5000 N
As the force of friction always acts opposite to the direction of applied force.
$\therefore$ Net accelerating force of engine
$= 40000 - 5000 = 35000$ N

(b) Mass 5 wagons
$= 2000 \times 5 = 10000$ kg
We know : F = ma
$35000 = 10000 \times a$

$\Rightarrow \quad a = \frac{35000}{10000} = 3.5\ m/s^2$

(c) Force of wagon 1 on wagon 2
F = ma
$= 8000 \times 3.5 = 28000$ N

Ex.16 An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 ms^{-2} ?

Sol. Mass of the vehicle (m) = 1500 kg
Negative acceleration (a) = $-1.7\ ms^{-2}$
$\therefore$ Force of friction between the road and vehicle
F = ma
$F = 1500 \times (-1.7) = -2550$ N
Negative sign means force is acting in the direction opposite to the direction of motion of the vehicle.

Ex.17 What is the momentum of an object of mass m, moving with a velocity v ?
(a) $(mv)^2$ (b) mv^2 (c) $1/2mv^2$ (d) mv

Sol. Correct Answer : mv

Ex.18 Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet ?

Sol. In order to move the cabinet with constant velocity, the net force acting on it should be zero, such that the forces are balanced.
This is possible only, if the frictional force is 200 N and acts in the direction opposite to the direction of motion of the cabinet.

Ex.19 Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 ms-' before the collision during which they stick together. What will be the velocity of the combined object after collision ?

Sol. Let the object be A and B moving from opposite direction in the same straight line.
$\therefore$ Momentum of A = m × v
= 1.5 x2.5 = 3.75 kg ms^{-1}
Also, Momentum of B
= m × (–v)
= 1.5 × (–2.5) = –3.75 kg ms^{-1}.
If, v is the velocity of the objects after collision, then Combined momentum after collision
= 3 × v
Using the law of conservation of momentum
Combined momentum of A and B = Momentum of A + Momentum of B
3 × v = 3.75 – 3.75
$\Rightarrow$ 3 × v = 0
$\Rightarrow$ v = 0

Ex.20 According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it, will probably not move. A student justifies this by answering that the two opposite and equal force cancel each other Comment on this logic and explain why the truck does not move.

Sol. The logic of the boy is completely wrong because the truck is going to move only due to the unbalanced force which is produced when the boy pushes the earth with his feet in the backward direction. However, this force produced by the reaction of earth is insufficient to overcome the force of friction offered by the wheels of the truck and hence, it does not move.

NCERT QUESTIONS WITH SOLUTIONS

Q.1 A hockey ball of mass 200g travelling at 10 ms^{-1} is struck by a hockey stick so as to return it along its original path with a velocity of 5 ms^{-1}. Calculate the change of momentum which occurred in the motion of the hockey ball by the force applied by the hockey stick.

Ans. Mass of ball, m = 200g = 0.2kg: initial velocity of ball, u_1 = 10 ms^{-1}; final velocity of ball, u_2 = −5 ms^{-1}. (Negative sign denotes that ball is moving in opposite direction)
Initial momentum of ball = mu_1 = 0.2 × 10 = 2 Ns
Final momentum of ball = mu_2 = 0.2 × (−5) = −1 Ns
∴ Change in momentum =
Final momentum − initial momentum = (−1) − (2) = − 3 Ns
Negative sign denotes that change in momentum is in the direction opposite to the direction of initial momentum of the ball.

Q.2 A bullet of mass 10 g travelling horizontally with a velocity of 150 ms^{-1} strikes a stationary wooden block and comes to rest in 0.03s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.

Ans. Mass of bullet, m = 10g = 0.01 kg; initial velocity of bullet, u = 150 ms^{-1}; final velocity of bullet, v = 0; time, t = 0.03s; acceleration of bullet, a = ?; force exerted by wooden block, F = ?; distance penetrated by bullet, s = ?

We know, $v = u + at$

or $0 = 150 + a \times 0.03$

or $-a \times 0.03 = 150$

or $a = \frac{-150}{0.03} = -5000\ ms^{-2}$

We know, $s = ut + \frac{1}{2}at^2$

$= 150 \times 0.03 + \frac{1}{2} \times (-5000) \times (0.03)^2$

= 4.5 − 2.25 = 2.25 m
We know, F = ma
Force acting on bullet,
F = 0.01 × (−5000) = − 50 N
Negative sign denotes that wooden block exerts force in a direction opposite to the direction of motion of the bullet.

Q.3 An object of mass 1 kg travelling in a straight line with a velocity of 10 ms^{-1} collides with, and sticks to a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Ans. For object: m_1 = 1kg; u_1 = 10 ms^{-1}
For wooden block; m_2 = 5 kg; u_2 = 0
Momentum just before collision = $m_1u_1 + m_2u_2 = 1 \times 10 + 5 \times 0$ = 10 kg ms^{-1}
Since, momentum is conserved, momentum before collision = momentum after collision = 10 kg ms^{-1}
Mass after collision = $(m_1 + m_2)$ = 1 + 5 = 6 kg
Let velocity after collision = v
∴ Momentum after collision = 6 × v
Using the law of conservation of momentum, momentum after collision = momentum before collision

$\therefore 6 \times v = 10$ or $v = \frac{10}{6} = 1.67\ ms^{-1}$

Q.4 An object of mass 100 kg is accelerated uniformly from a velocity of 5 ms^{-1} to 8 ms^{-1} in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Ans. Mass of object, m = 100 kg; initial velocity, u = 5 ms^{-1}; final velocity, v = 8 ms^{-1}; time, t = 6 s

Initial momentum = mu = 100 × 5 = 500 Ns

Final momentum mv = 100 × 8 = 800 Ns

Force exerted on the object

$$F = \frac{mv - mu}{t} = \frac{800 - 500}{6} = \frac{300}{6} = 50 \text{ N}$$

Q.5 Akhtar, Kiran and Rahul were riding in a motorcar that was moving with a high velocity on an express-way when an insect hit the windshield and got stuck on the windscreen, Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result the insect died. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and change in their momentum. Comment on these suggestions.

Ans. Kiran's suggestion is not correct because momentum is always conserved i.e. change in momentum of insect must be equal and opposite to that of motorcar.

Akhtar's suggestion is also not correct.

Rahul's suggestion is correct i.e., insect and motorcar experience same force and change in momentum. However, the insect dies, because it is unable to bear the large force and large change in momentum.

Q.6 How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm and does not rebound? Take its downward acceleration to be 10 ms^{-2}.

Ans. Mass of dumb-bell, m = 10kg; initial velocity, u = 0; final velocity, v = ?; distance, s = 80 cm = 0.8 m; acceleration, a = 10 ms^{-2}

We know $v^2 - u^2 = 2as$

$v^2 - (0)^2 = 2 \times 10 \times 0.8$

$v^2 = 16$

$v = \sqrt{16} = 4 \text{ ms}^{-1}$

$\therefore$ Momentum of dumb-bell transferred to ground = mv = 10 × 4 = 40 kg ms^{-1}.

Q.7 The following is the distance-time table of an object in motion

Time	0	1	2	3	4	5	6	7
Distance	0	1	8	27	64	125	216	343

(a) What conclusion can you draw about the acceleration? Is it constant, increasing, decreasing or zero?

(b) What do you infer about the force acting on the object?

Ans. (a) A careful observation of the distance-time table shows that $s \propto t^3$.

It is known that, in uniform motion $s \propto t$, and for motion with uniform acceleration $s \propto t_2$.

In the present case, $s \propto t_3$. Therefore, we conclude in this case that acceleration must be increasing with time.

(b) As F ma, therefore, $F \propto a$. Hence, the force must also be increasing with time.

Q.8 Two persons manage to push a motorcar of mass 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 ms^{-2}. With what force does each person push the motorcar? (Assume that all persons push the motorcar with the same muscular effort.)

Ans. As two persons can make the motorcar move with uniform velocity, it is clear that total force applied by them on the motorcar is balanced by the force of friction acting in the opposite direction. It is force of one more person which produces an acceleration of 0.2 ms^{-2}.

$\therefore$ Force of one person mass × acceleration 1200 × 0.2 = 240 N

Q.9 A hammer of mass 500 g, moving at 50 ms^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

Ans. the force of nail on the hammer

$$F = \frac{\text{Change in momentum of hammer}}{\text{Time}}$$

$$F = \frac{m(v-u)}{t} = \frac{0.5(0-50)}{0.01} = 2500 \text{ N}$$

Negative sign denotes that the force of nail on the hammer is acting in the direction opposite to that of motion of hammer.

Q.10 A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Ans. (i) initial velocity of the car, u = 90 km/h = 25 ms^{-1}; time, t = 4s; acceleration, a = ?

We know, $v = u + at$

$5 = 25 + a \times 4$

$\therefore \quad -a \times 4 = 20$ or $a = \frac{-20}{4} = -\ ms^{-2}$

(ii) Change in momentum, $\Delta p = m(v - u)$

$= 1200\ (5 - 25) = 1200 \times (-20) = -\ 24000$ Ns

(iii) Magnitude of force

$$F = \frac{m(v-u)}{t} = \frac{-24000}{4} = -6000\text{N}$$

Q.11 A large truck and a car, both moving with a velocity of magnitude v, have a head-on collision. If the collision lasts for 1 s,

(a) Which vehicle experiences greater force of impact ?

(b) Which vehicle experiences greater change in momentum?

(c) Which vehicle experiences greater acceleration?

(d) Why is the car likely to suffer more damage than the truck?

Ans. Let mass of truck M; mass of car m; velocity of truck = v; time for which collision lasts, t = 1s; velocity of car = -v (Negative sign for opposite direction of motion).

(a) On collision, both the vehicles experience the same force, as action and reaction are equal.

(b) Change in momentum of truck is equal and opposite to change in momentum of car, i.e., both the vehicles experience the same change in momentum.

(c) As acceleration = force/mass, and force on each vehicle is same, therefore, acceleration $\propto \frac{1}{\text{mass}}$. As mass of car is smaller, therefore, acceleration of car is greater than the acceleration of the truck.

(d) The car is likely to suffer more damage than the truck, as it is lighter. The acceleration i.e. change in velocity/s of car is more than that of the truck.

EXERCISE – I BOARD PROBLEMS

Q.1 Give two examples in each case, of a force that:
(i) Lifts (ii) Pushes (iii) Pulls
(iv) Stretches (v) Compresses
(vi) Resists (vii) Attract (viii) Squeeze.

Q.2 State and explain the law of inertia (or Newton's first law of motion)

Q.3 You are hurt when you kick a stone. Why?

Q.4 Give an example of a force that merely changes the direction of motion of a body.

Q.5 Define (i) force (ii) dyne (iii) newton.

Q.6 State Newton's second law of motion.

Q.7 What is the SI unit of force ?

Q.8 Name the cgs unit of force. How is it related to Newton ?

Q.9. While standing in a bus, we fall backward if the bus suddenly starts. Why?

Q.10 The passengers fall forward when a speeding bus stops suddenly. Why?

Q.11 Newton's first law of motion is also called law of inertia. Why?

Q.12 Air is thrown on a sail attached to a boat from an electric fan placed on the boat. Will the boat start moving?

Q.13 A bird is sitting on the floor of a wire cage and the cage is in the hand of a boy the bird starts flying in the cage. Is there any change in the weight of the cage?

Q.14 There is some water is the beaker placed on the pan of a spring balance. If we dip one finger in this water without touching the bottom of the beaker, then what would be the effect on the reading of the balance?

Q.15 An athlete always runs some distance before taking a jump? Why?

Q.16 According to Newton's third law, every force is accompanied by equal and opposite forces how then can anything move?

Q.17 Give the magnitude and direction of the net force acting on.
(a) a drop of rain falling down with a constant speed.
(b) a cork of mass 10 g floating on water.
(c) a kite skilfully held stationary in the sky.

Q.18 Calculate the force required to produce an acceleration of 5 m/s^2 in a body of mass 2.4 kg.

Q.19 A body of mass 2.5 kg is moving with a velocity of 20 m/s. Calculate its momentum.

Q.20 A force acts for 0.2 s on a body of mass 2.5 kg initially at rest. The force then ceases to act and the body moves through 4m in the next one second. Calculate the magnitude of force.

Q.21 A ball of mass 20 gm is initially moving with a velocity of 100 m/s. On applying a constant force on the ball for 0.5s, it acquires a velocity of 150 m/s. Calculate the following :
(i) Initial momentum of the ball
(ii) Final momentum of the ball
(iii) Rate of change of momentum
(iv) Acceleration of the ball
(v) Magnitude of the force applied

Q.22 A cricket ball of mass 200 gm moving with a speed of 40 m/s is brought to rest by a player in 0.04s. Calculate the following :
(i) Change in momentum of the ball,
(ii) Average force applied by the player.

Q.23 A motorcycle is moving with a velocity of 108 km/hr and it takes 5 s to stop it after the brakes are applied. Calculate the force exerted by the brakes on the motorcycle if its mass along with the rider is 250 kg.

Q.24 A rifle of mass 5 kg fires a bullet of mass 40 gm. The bullet leaves the barrel of the rifle with a velocity 200 m/s. If the bullet takes 0.004 s to move through the barrel, calculate the following :
(i) recoil velocity of the rifle and
(ii) the force experienced by the rifle due to its recoil.

Q.25 A bullet of mass 20 gm moving with a velocity 200 m/s gets embedded into a wooden block of mass 980 gm suspended by a string. Calculate velocity acquired by the combined system.

Q.26 Due to internal combustion inside a rocket, gases are ejected at the rate of 2.4 kg/ minute. The velocity of the gases with respect to the rocket is 400 m/s. Calculate force exerted on the rocket

Q.27 A rifle man, who together with his rifle has a mass of 100 kg, stands on a smooth surface fires 10 shots horizontally. Each bullet has a mass 10 gm a muzzle velocity of 800 m/s.What velocity does rifle man acquire at the end of 10 shots?

Q.28 A body of mass 1 kg strikes elastically with another body at rest and continues to move in the same direction with one fourth of the initial velocity. What will be the mass of the other body

Q.29 A block of mass m_1 = 150 kg is at rest on a very long frictionless table, one end of which is terminated in a wall. Another block of mass m_2 is placed between the first block and the wall, and set in motion towards m_1 with constant speed u_2. Assuming that all collisions are completely elastic, find the value of m_2 for which both blocks move with the same velocity after m_2 has collided once with m_1 and once with the wall. (The wall has effectively infinite mass.)

Q.30 What will be the pressure in N/m^2 at a depth of 15cm in brine of density 1.2 gm/cm^3 ?

Q.31 Calculate the density of a liquid if the pressure at a pt 30 m below its surface is 32×10^4 N/m^2.

Q.32 A force of 150 N is applied on an area of 1.5 m^2. Calculate the pressure exerted.

Q.33 A force of 500 dynes is applied on an area of 20 cm^2. Calculate the pressure exerted.

Q.34 A body weighs 300 gmf in air and 260 gmf when completely immersed in water. Calculate the following :

(i) loss in weight of the body

(ii) upthrust on the body.

Q.35 A solid block of volume 2 litres has a weight of 80 N. What will be its weight when immersed completely in water ?

Q.36 A solid block of density D has a weight W in air is fully immersed in a liquid of density d. Calculate its apparent weight when fully immersed in liquid.

Q.37 A body weighs 30 N in air and 26 N when fully immersed in water. Calculate its relative density.

Q.38 Relative density of copper is 8.8. What is its density in SI system ?

Q.39 A solid weighs 60 gmf in air and 52 gmf when completely immersed in water. Calculate the following :

(i) upthrust,

(ii) volume of the solid,

(iii) relative density of the solid

Q.40 For determining the relative density of a liquid, following observations are taken. Weight of solid in air = 0.200 kgf; Weight of solid immersed in liquid = 0.160 kgf; Weight of solid in water = 0.0150 kgf. Calculate the following :

(i) Loss of weight of solid in liquid.

(ii) Loss of weight of the solid in water.

(iii) Relative density of the liquid.

Q.41 When a force of 40 N is applied on a body it moves with an acceleration of 5 ms^{-2}. Calculate the mass of the body.

Q.42 It is required to increase the velocity of a scooter of mass 80 kg from 5 to 25 ms^{-1} in 2 sec. Calculate the force required.

Q.43 Two blocks made of different metals identical in shape and sizes are acted upon by equal forces which cause them to slide on a horizontal surface. The acceleration of the second block is found to be 5 times that of the first. What is the ratio of the mass of the second to the first?

Q.45 An object undergoes an acceleration of 8 ms^{-2} starting from rest. Find the distance travelled in 1 second.

EXERCISE – II OLYMPIAD QUESTIONS

Q.1 An external influence which changes or tends to change the state of rest or uniform motion of body or its dimensions is called :

(A) momentum (B) force

(C) moment of force (D) pressure

Q.2 Equal and opposite forces acting on a body which do not change its state of rest or uniform motion are called:

(A) like parallel forces (B) unlike parallel forces
(C) balanced forces (D) all the above

Q.3 The unequal and opposite forces acting on a body, which change its state of rest or uniform motion are called:

(A) unbalanced forces (B) balanced forces
(C) like parallel forces (D) all the above

Q.4 Force of friction always acts in the direction:

(A) of applied force

(B) opposite to the direction of applied force

(C) at right angles to the direction of applied force

(D) none of the above

Q.5 When balanced forces act on a body, the body:

(A) must remain in its state of rest

(B) must continue moving with uniform velocity, if already in motion

(C) must experience some acceleration

(D) both (A) and (B)

Q.6 When unbalanced forces act on a body, the body:

(A) must move with uniform velocity
(B) must remain at rest

(C) must experience acceleration

(D) must move in a curved path

Q.7 If no external force acts on a body, it will :

(A) move with more speed

(B) change its shape

(C) break into pieces

(D) either remain in its state of rest or in uniform motion.

Q.8 If a body is allowed ti freely fall from a height, its speed increases continuously. It is because:

(A) air does not exert frictional force

(B) magnetic force of earth increases its speed

(C) gravitational force of earth increases its speed

(D) pressure of air forces it downward

Q.9 A force of magnitude' F' acts on a body of mass 'm'. The acceleration of the body depends upon:

(A) volume of body (B) density of body
(C) area of body (D) mass of body

Q.10 Force remaining constant, if the mass of body increases, its acceleration is likely to :

(A) increase (B) remain same

(C) decrease (D) sometimes increases and sometimes decreases

Q.11 A force F produces an acceleration 'a' in a body. The same force produces and acceleration 4a in another body. The mass of other body is :

(A) four times the mass of first body
(B) four times less the mass of other body

(C) mass does not play role

(D) none of the above

Q.12 When a running motorbike accelerates suddenly, the pillion rider has a tendency to fall backward. This is an example of:

(A) Newton's first law of motion

(8) Newton's second law of motion

(C) Newton's third law of motion

(D) Newton's law of gravitation of motion

Q.13 Which is the incorrect statement?

A spaceship continues moving in space with uniform speed because:

(A) no force of friction due to air acts on it
(B) its mass is zero in space

(C) no force of gravitation acts on it
(D) no force of friction due to earth acts on it

Q.14 The impact which a body can produce due to the combined effect of mass and velocity is called:

(A) momentum (B) force

(C) moment of force (D) pressure

Q.15 The SI unit of momentum is :

(A) newton (B) newton-second
(C) dyne (D) dyne-second

Q.16 The tendency of a body to continue in its state of rest or uniform motion, even on the application of external force is called:

(A) force (B) momentum
(C) inertia (D) impulse

Q.17 A body will continue in its state of rest or uniform motion in a straight line, unless acted by some external force. The statement represents :

(A) Newton's second law of motion
(B) Newton's first law of motion
(C) Newton's third law of motion
(D) Law of conservation of momentum

Q.18 The magnitude of inertia of a body is determined by its:

(A) mass (B) weight
(C) velocity (D) acceleration

Q.19 Momentum is a:

(A) vector quantity
(B) scalar quantity
(C) fundamental quantity
(D) none of the above

Q.20 A body P has mass 2 m and velocity 5 v. Another body Q has mass 8 m and velocity 1.25 v. The ratio of momentum of P and Q is :

(A) 2 : 1 (B) 1 : 1
(C) 1 : 2 (D) 3 : 2

Q.21 The magnitude of a physical quantity is 8.5 Ns. The physical quantity is :

(A) force (B) momentum
(C) pressure (D) moment of force

Q.22 There is a rubber ball and a stone ball of same size. If both balls are at rest:

(A) rubber ball has more inertia than stone ball
(B) stone ball has more inertia than rubber ball
(C) both have same inertia
(D) none of the above.

Q.23 When we vigorously a shake branch of a tree, some leaves get detached. It is due to the:

(A) inertia of rest
(B) inertia of motion
(C) some leaves are loosely held by the branch
(D) none of the above.

Q.24 When the driver of a fast moving car suddenly applies brakes, the passengers in the car:

(A) fall backward (B) fall forward
(C) are not affected (D) none of the above.

Q.25 A batsman hits a cricket ball, which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows down to stop because:

(A) the batsman did not hit the ball hard
(B) velocity of ball is proportional to force acting on it
(C) there is force on the ball opposing its motion
(D) there is no unbalanced force on the ball and hence it comes to rest

Q.26 The force of freely falling body is directly proportional to:

(A) mass of body (B) acceleration of body
(C) velocity of body (D) both (A) and (B)

Q.27 The principle of conservation of linear momentum states that in a system it :

(A) cannot be changed
(B) can be changed, if internal forces act on it
(C) can be changed, if external forces act on it
(D) none of the above

Q.28 Action-reaction forces:

(A) act on same body
(B) act on different bodies
(C) act along different lines
(D) act in same direction

Q.29 A porter is carrying a weight of 200 N on his head. If the force exerted on his head is taken as action, then the reaction force is exerted by :

(A) the head on the weight
(B) the weight on the earth
(C) the earth on the porter
(D) the earth on the weight

Q.30 Which of the following are vector quantities:

(A) momentum (B) velocity
(C) force (D) all of the above.

Q.31 Two bodies collide at the same time. Which of the following is conserved?

(A) velocity (B) kinetic energy
(C) momentum (D) force

Q.32 Impulse is equal to :

(A) the change in force
(B) the change in momentum
(C) the change in velocity
(D) all the above

Q.33 A rocket works on the principle of:

(A) conservation of energy

(B) conservation of linear momentum

(C) conservation of inertia

(D) conservation of force

Q.34 When a speeding car takes a sharp turn, the persons sitting in it experience outward pull. This happens due to:

(A) inertia of direction

(B) change in momentum

(C) change in acceleration

(D) none of the above

Q.35 The ratio of force and acceleration of a moving body is the measure of its:

(A) velocity (B) momentum

(C) mass (D) impulse

Q.36 When you kick a stone, you get hurt. Due to which property this happens?

(A) inertia of stone

(B) velocity of the kick

(C) momentum of the kick

(D) reaction of the stone

Q.37 A motor bike accelerates on the horizontal road due to the force exerted by :

(A) the engine of motorbike

(B) the earth

(C) the driver on the motorbike

(D) none of the above.

Q.38 Impulse has same unit as that of:

(A) force (B) pressure

(C) momentum (D) moment of force

Q.39 By Newton's second law, the physical quantity which can be calculated, if we know the magnitude of force on a given mass is :

(A) velocity

(B) acceleration

(C) momentum

(D) none of the above.

Q.40 A body is moving with a constant momentum. The motion of the body is :

(A) uniform velocity

(B) accelerated

(C) de-accelerated

(D) none of the above.

Q.41 A cracker at rest explodes into two equal parts. These parts will move in :

(A) opposite direction with different velocities

(B) same direction with different velocities

(C) same direction with same velocities

(D) opposite direction with same velocities

Q.42 A batsman has a choice to use heavy or light bat, while facing a fast bowler. He will prefer:

(A) light bat, because handling it is easy

(B) heavy bat, so that he can handle it firmly

(C) heavy bat, because it will recoilless

(D) none of the above.

Q.43 A vehicle has a mass of 1500 kg. If the vehicle is to be stopped with a negative acceleration of 1.7 ms^{-2}, the force of friction between the vehicle and road is :

(A) –2250 N (B) –2050 N

(C) –2550 N (D) none of the above.

Q.44 A man while running at a constant acceleration of 3.5 ms^{-2}, develops a force of 280 N. The mass of man is:

(A) 80 kg (B) 85 kg

(C) 75 kg (D) 60 kg

Answers

1.	B	**2.**	C	**3.**	A	**4.**	B
5.	D	**6.**	C	**7.**	D	**8.**	C
9.	D	**10.**	C	**11.**	B	**12.**	A
13.	B	**14.**	A	**15.**	B	**16.**	C
17.	B	**18.**	A	**19.**	A	**20.**	B
21.	B	**22.**	B	**23.**	A	**24.**	B
25.	C	**26.**	D	**27.**	A	**28.**	B
29.	C	**30.**	D	**31.**	C	**32.**	B
33.	B	**34.**	A	**35.**	C	**36.**	D
37.	B	**38.**	C	**39.**	B	**40.**	D
41.	D	**42.**	C	**43.**	C	**44.**	A

EXERCISE – III MULTIPLE CHOICE QUESTIONS

SECTION-A

- **Fill in the blanks**

1. The forces of action and reaction have _____ magnitudes but _____ directions.
2. A body kept at rest will remain _____ if no unbalanced force acts on it.
3. The linear momentum of a system remains constant if no_____ force acts on it.

SECTION-B

- **Multiple choice question with one correct answers**

1. A force of 100 N acts on 50 kg for 2 seconds. The same force acts on 25 kgs for 2 seconds. The ratio of the momenta produced and the accelerations caused in two bodies respectively are –

   (A) 1 : 1, 2 : 1 (B) 1 : 1, 1 : 2 (C) 1 : 2, 1 : 1 (D) none of these

2. The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the child. The average retarding force on the vehicle? The mass of the three-wheeler is 335 kg and mass of the driver is 65 kg.

   (A) 1025 N (B) 10 N (C) 1000 N (D) none of these

3. A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 m/s, the recoil speed of the gun –

   (A) 14 m/s (B) 0.012 m/s (c) 0.016 m/s (D) 100 m/s

4. A horizontal force of 600 N pulls two masses 10 kg and 20 kg (lying on a frictionless table) connected by a light string. The tension in the string , if the 20 kg mass is pulled

   (A) 200 N (B) 400 N (C) 100 N (D) 50 N

5. Two masses 8 kg and 12 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. The acceleration of the masses, when the masses are released is ($g = 10\ m/s^2$)

   (A) 6 m/s^2 (B) 4 m/s^2 (C) 10 m/s^2 (D) 2 m/s^2

6. Two billiard balls each of mass 0.05 kg moving in opposite directions with speed 6 m/s collide and rebound with the same speed. The magnitude of impulse imparted to each ball due to the other –

   (A) 0.6 kg m/s (B) zero (C) 6 kg m/s (D) none of these

SECTION-C

- **Assertion & Reason**

  Instructions: In the following questions as Assertion (A) is given followed by a Reason (R). Mark your responses from the following options.

  (A) Both Assertion and Reason are true and Reason is the correct explanation of 'Assertion'
  (B) Both Assertion and Reason are true and Reason is not the correct explanation of 'Assertion'
  (C) Assertion is true but Reason is false
  (D) Assertion is false but Reason is true

1. **Assertion:** Large force is required to move a body uniformly along a straight path
   Reason: A body moving with uniform acceleration has a constant force acting on it.
2. **Assertion:** Linear momentum of a body changes when the body is moving in a circle.
   Reason: In uniform circular motion the velocity changes because of change in direction.
3. **Assertion:** A player lowers his hands while catching a ball.
   Reason: Impulse is the time rate of change of momentum.

4. **Assertion:** Mass is a measure of inertia of the body in linear motion.
   Reason: Smaller the mass, smaller is the force required to change its state.

SECTION-D

- **Match the following (one to one)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. Only One entries of column-I may have the matching with the same entries of column-II and one entry of column-II Only one matching with entries of column-I

1.

Column I	**Column II**
(A) Measure of inertia	(P) Force × time
(B) Impulse	(Q) Mass × velocity
(C) Momentum	(R) Mass × acceleration
(D) Newton's second law of motion	(S) Mass

EXERCISE – IV MULTIPLE CHOICE QUESTIONS

SECTION-A

- **Multiple choice question with one correct answers**

1. If a body is in equilibrium under a set of non-collinear forces, the minimum number of forces has to be:
   (A) Four (B) Three (C) Two (D) Five
2. Bullets of 0.03 kg mass each hit a plate at the rate of 200 bullets per second, with a velocity of 50 m/sec. reflect back with a velocity of 30 m/sec. The average force acting on the plate, in newtons is:
   (A) 120 (B) 180 (C) 300 (D) 480
3. A force of 5 N making an angle θ with the horizontal acting on an object displaces it by 0.4 m along the horizontal direction.If the object gains kinetic energy of 1 J, the horizontal component of the force is:
   (A) 1.5 N (B) 2.5 N (C) 3.5 N (D) 4.5 N
4. A force of 50 dynes is acted on a body of mass 5g which is at rest for an interval of 3sec. The impluse is
   (A) 0.15×10^{-3} Ns (B) 0.98×10^{-3} Ns (C) 1.5×10^{-3} N.s (D) 2.5×10^{-3}
5. Swimming is possible by the:
   (A) first law of motion (B) second law of motion
   (C) third law of motion (D) Newtons law of gravition
6. A cricket player catches a ball of mass 0.1 kg, moving with a speed 10 m/s in 0.1 second. Froce exerted by him is (N)
   (A) 4 (B) 2 (C) 1 (D) 10

SECTION-B

- **Multiple choice question with one or more than one correct answers**

1. Newton's first law of motion defines
   (A) Force (B) Inertia (C) Momentum (D) Acceleration
2. Which of the following statements is/are not correct ?
   (A) A force is needed to keep a particle moving along a straight line with uniform velocity.
   (B) The same force for the same time causes the same change in momentum for different bodies.
   (C) Frictional force opposes both motion as well as relative motion.
   (D) It is not motion, but relative motion that the frictional force opposes.
3. Which of the following statements is/are correct ?
   (A) Momentum has both direction and magnitude
   (B) Momentum is a scalar quantity
   (C) The SI unit of momentum is kilogram-metre per second.

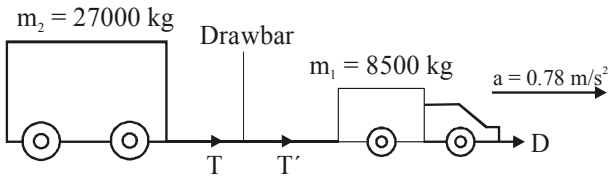
(D) The rate of change of momentum of an object is in the direction of force.

4. Action-Reaction forces act
   (A) on the same body (B) on the different bodies
   (C) along the same lines (D) in the same direction
5. A constant force acts on an object of mass 4 kg for a duration of 1 second. It increases the object velocity from 4 ms^{-1} to 6 ms^{-1}. Select the correct options.
   (A) Magnitude of the applied force is 8 N
   (B) Final velocity of the object if the force applied for 5 sec is 24 m/s
   (C) Change in momentum in 1 sec is 8 kg m sec^{-1}
   (D) Change in momentum of object during 5 sec is 56 kg m/sec
6. A girl of mass 30 kg jumps with a horizontal velocity of 4 m sec^{-1} onto a stationary cart with frictionless wheels. The mass of cart is 2 kg. Select the correct options
   (Assuming that there is no external unbalanced force working in the horizontal direction)
   (A) The total momentum of the girl and the cart before the interaction is 120 kg m sec^{-1}
   (B) The total momentumof the girl and the cart after the interaction is 120 kg m sec^{-1}
   (C) The girl on cart will move with a velocity 15 m sec^{-1} in the direction in which the girl jumped
   (D) The girl on cart will move with a velocity 15/4 m sec^{-1} in the opposite direction in which the girl jumped

SECTION-C

- **Comprehension**

A truck is hauling a trailer along a level road as figure illustrates. The mass of the truck is m_1 = 8500 kg and that of the trailer is m_2 = 27000 kg.



The two move with an acceleration of a = 0.78 m/s^2. Ignore the retarding forces of friction and air resistances.

1. The magnitude of the tension in the horizontal drawbar between the trailer and the truck
   (A) 21000 N (B) 28000 N (C) 60000 N (D) None of these
2. The force D that propels the truck forward
   (A) 21000 N (B) 28000 N (C) 60000 N (D) None of these
3. The action and reaction forces are
   (A) D and T (B) T and T´ (C) D and T´ (D) None of these

SECTION-D

- **Match the following (one to many)**

Column-I and **column-II** contains **four** entries each. Entries of column-I are to be matched with some entries of column-II. One or more than one entries of column-I may have the matching with the some entries of column-II and one entry of column-II may have one or more than one matching with entries of column-I

1.

Column I	**Column II**
(A) A rocket works on the principle of	(P) First law of motion
(B) Recoiling of gun can be explained by	(Q) Second law of motion
(C) The law which defines the force is	(R) Third law of motion
(D) The law which gives the quantitative measurement of force is	(S) Conservation of momentum

ANSWER KEY

EXERCISE-III

SECTION-A

1. Equal, Opposite
2. At rest
3. Unbalanced

SECTION-B

1. (B)
2. (C)
3. (C)
4. (A)
5. (D)
6. (A)

SECTION-C

1. (D)
2. (A)
3. (C)
4. (A)

SECTION-D

1. (A)-(S), (B)-(P), (C)-(Q), (D)-(R)

EXERCISE-IV

SECTION-A

1. (B)
2. (D)
3. (B)
4. (C)
5. (C)
6. (D)

SECTION-B

1. (A,B)
2. (A,C)
3. (A,C,D)
4. (B,C)
5. (A,C)
6. (A,B)

SECTION-C

1. (A)
2. (B)
3. (B)

SECTION-D

1. (A)- (R,S), (B)-(R,S), (C)-(P), (D)-(Q)